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Advancing Translational Research by Enabling Collaborative Teamwork: The TRACT Approach

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Abstract

Background: The work of multidisciplinary research teams (MDRTs) is vital for translational research. The objectives of this study were 1) to understand the structure and function of MDRTs, and 2) to develop effective strategies to enhance collaboration among team members. Methods and Findings: Semi-structured interviews were conducted with 23 participants involved in multidisiplinary research work at two San Antonio, Texas, institutions. Interview materials were tape-recorded, transcribed, and content analyzed using qualitative methods. Themes that emerged from the content analysis were used to develop and refine strategies to enhance the work of MDRTs. The findings showed that MDRTs operate through multiple cycles of: 1) team formation, 2) team collaboration, 3) sustainable collaborative activities, and 4) team maturity. Content analysis identified four interrelated basic elements within the MDRT tract that facilitate team cycles: 1) shared interest/vision among agreeable team leader and members, 2) viable means of communication, 3) available resources, and 4) perceived gain/benefit of teamwork.

Conclusions: Our findings highlighted several opportunities and challenges in the formation, dynamics, and growth of MDRTs. Effective strategies to enhance teamwork should levearge these opportunities and address challenges, taking into consideration the interdependent aspects of the basic elements within the MDRTs tract.

Keywords: Multidisciplinary research teams; Translational research; Team science; Qualitative; TRACT

Introduction

The work of multidisciplinary research teams (MDRTs) is an integral part of translational research [1-3]. Clinical and translational science encompass a broad spectrum of research, emphasizing and extending the bidirectional aspects of basic discoveries to community-based epidemiologic and health services studies to improve human health [4]. As such, clinical and translational research are multidimensional, cross-cutting disciplines that consist of investigative teams from many different specialties. Therefore, building MDRTs to synthesize and translate knowledge from laboratory and/or clinical investigations into clinical applications has emerged as one of the major themes in the National Institutes of Health (NIH) Roadmap initiative [4]. The NIH Roadmap focused on efforts that no single or small group of institutions or centres could or should conduct on their own. The initiative is in place to accelerate efficient and effective collaborative studies across disciplines. Building and enhancing the work of MDRTs is also the goal of the Novel Clinical and Translational Methodologies (NCTM) program at the Institute for Integration of Medicine and Science (IIMS), which promotes multidisciplinary efforts [5]. The mission of the IIMS is to integrate clinical and translational research and career development across all schools at the University of Texas Health Science

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Center at San Antonio (UTHSCSA) and among its diverse public and private partners in South Texas (http://iims.uthscsa.edu/collaboration.html).

An MDRT is defined as a group of professionals who have diverse expertise and work independently or sequentially to address common, complex problems within their tract [6]. In this article, MDRT tract is defined as a system (virtual or physical) that has the basic elements (e.g., support for information technology and other infrastructure resources required to enhance collaboration) needed to advance the work of an MDRT. Individuals in an MDRT learn, interconnect, self-organize, and interact in a way that shows nonlinear dynamic behaviour. The teamwork involved achieves scientific breakthroughs that would not be possible by individual effort [7]. MDRTs differ from other cross-disciplines (i.e., inter-/trans-) in that they are not so much integrative as they are additive. MDRTs draw on knowledge from different disciplines but stays within their boundaries. Interdisciplinarity analyzes, synthesizes and harmonizes links between disciplines into a coordinated and coherent whole. Therefore, multidisciplinary research depends and thrives by the work of complementary scientific contributions [8]. All teams must integrate, synthesize, and share information, and to accomplish their goals, they need to coordinate and cooperate as tasks shift [9]. Each expert works from within their own thematic area in concurrence with another, adding to another's research on a common subject. A good example of MDRT would be a computer scientist who works with basic science scientists (e.g., team members with expertise in molecular genetics) to apply computer science theories to advance a bioinformatics project (e.g., next generation sequencing to examine the genetic basis of common diseases). The MDRT members work together to design, conduct, implement and evaluate the project [10].

Although the efforts of multidisciplinary teams are continually promoted, little has been established in the science behind them. The science of team science is an area of study involved with understanding and using factors that influence initiatives of team science [11]. The field as a whole focuses not on the phenomena addressed by particular team science initiatives, but rather on understanding and enhancing the antecedent conditions, collaborative processes, and outcomes associated with team science initiatives, generally including their scientific discoveries, educational outcomes, and translation of research findings into new clinical practices and public policies [11,12]. As such, this study was conducted to examine the structure and function of MDRTs to better understand, enable, and enhance their collaborative efforts to advance translational research.

Methods

We used a qualitative approach to elicit researchers' views and experiences about working in MDRTs. A panel of experts in translational, health services, and science-of-team-science research was invited to evaluate and revise several open-ended questions regarding the structure and function of an MDRT. The panel of experts included 9 professionals (5 female, 4 male) of both MD and PhD degrees from multidisciplinary fields such as anthropology, psychology, health services research, medicine, and biostatistics. The panel met several times to revise a set of open-ended

questions related to the science of team science. The revised open-ended questions were used to conduct semi-structured interviews with researchers working at the University of Texas Health Science Center at San Antonio (UTHSCSA) and the University of Texas at San Antonio (UTSA).

Recruitment

To avoid sampling bias, initial letters of invitation were sent to all eligible researchers (N = 67) participating in MDRT investigations at UTHSCSA and UTSA. MDRT investigators were identified using IIMS collaborative tools such as Collexis, which is linked to both BiomedExperts and the Collexis Expert Platform for Translational Research (CPTR) (http://iims.uthscsa.edu/collaboration.html). Contact information for MDRT investigators (e.g., name, email, and address) was obtained from the local directories of UTHSCSA and UTSA. The letters described the purpose of the study and invited researchers to participate in an in-depth semi-structured interview. The interviews focused on three main topics: 1) team formation, collaboration, and sustainability, as expressed by the presence of interpersonal, environmental, and organizational factors that facilitate team dynamics across various research domains; 2) team functioning, as articulated by leadership styles, communication networks, and conflict resolution strategies; and 3) facilitators and barriers to MDRT work. Selected open-ended questions used during the semi-structured interviews are presented in Appendix 1. All interview materials were tape-recorded, transcribed, and content analyzed using NVivo software.

Considerable flexibility during the interviews allowed participants to discuss issues that were most important to them. The sample size of 23 participants (20 investigators; 3 staff members – see Table 1) was appropriate to generate important themes related to an MDRT experience and allowed a high level of saturation across different disciplines. Interviews were conducted at participants' offices/departments. All semi-structured interviews lasted about one hour and were conducted by an experienced qualitative researcher who avoided leading but allowed probing questions, ensuring answers were as complete and unbiased as possible. Content analysis was performed on the transcripts of the semi-structured interviews.

Data Analysis

Based on participants' responses, we constructed and defined a series of temporary categories and established a filing and retrieval system for them. We then designed a primary database with variables based on both open-ended and close-ended (i.e., demographic) responses. Content analysis was conducted in three steps. First, for each participant, we built an initial matrix that consisted of columns representing the interview questions and cells presenting the researcher's response to the questions extracted from the interview. The text in the cells was either direct quotations or summations of responses. Second, we examined the initial matrices to identify patterns across cases for each person. Patterns recognized in this analysis formed the basis of additional categorization to construct overall higher-level matrices. Lastly, higher-level matrices were summarized into tables representing participants'

Table 1

Participant characteristics (*N* = 23)

Age (years)		Mean: 39.5 Range: 35–50
Characteristic		Frequency (%)
Gender	Female Male	15 (65%) 8 (35%)
Ethnic origin	Mexican American Non-Hispanic White Asian American	8 (35%) 9 (39%) 6 (26%)
Employment status at the time of the interview	Researcher Staff	3 (13%) 20 (87%)
Rank status (*N* = 20)	Junior faculty Senior faculty Recently transitioned to tenured faculty	15 (75%) 3 (15%) 2 (10%)
Academic institution	UTHSCSA School of Medicine Dental School School of Nursing UTSA College of Education College of Liberal and Fine Arts College of Science and Engineering	 8 (35%) 3 (13%) 4 (17%) 4 (17%) 1 (5%) 3 (13%)

responses. Matrices were initially examined by each column "to identify patterns across cases" (see Table 2 and 3); however, the final analysis included overall gestalt. All interview materials were checked and evaluated to ensure consistency in coding and classification procedures [13,14]. The initial analysis to build the coding plan was conducted primarily by one researcher using qualitative methods, and another team member independently read half of the transcripts to confirm the integrity of the emerging codes. Inter-coder reliability was ensured through a coding comparison method. Once development of the coding tree was advanced, one researcher coded the entire transcript set. Then, another researcher and a project staff member re-coded a random selection (20%) of the coded materials. Agreement between the two researchers in re-coding was acceptable (kappa coefficient = .75) by consensus standards. A similar iterative process was used to identify and verify emerging themes. NVivo was used to perform content analysis. Quantitative analysis of responses involved calculating basic descriptive statistics, such as means, standard deviations, and percentages. The Institutional Review Board ethics at the University of Texas Health Science Center at San Antonio approved the study protocol.

Table 2

Facilitators and barriers to MDRT formation (*N* = 20)

Main categories related to the identified themes	Emergent themes	Frequency (%)
Initial recruitment to MDRT		
	Had prior interactions	8 (40%)
	Introduced by colleagues	5 (25%)
	Seminars/web search	7 (35%)
Factors facilitating team formation		
Shared interest/vision among agreeable team members/leader	Established relationship with individuals	11 (55%)
	Finding people with shared or overlapping interests	4 (20%)
	Trust	2 (10%)
	Agreeable personalities	2 (10%)
Resources	Having funds and time from institution	1 (5%)
Barriers to team formation		
Lack of members with similar interest Non-agreeable team members/leader	Finding members with different scientific backgrounds	9 (45%)
	Non-social members/personality differences	4 (20%)
Perceived value of teamwork	Lack of incentives for working in teams	3 (15%)
Limited resources	Lack of institutional support	2 (10%)
	Time and scheduling demands	2 (10%)

Results

Participant Characteristics

Semi-structured interviews were conducted with 23 participants (64% female; 36% male). The majority (N = 20, 87%) were researchers who actively participated in multidisciplinary collaborations. Three of the participants (13%) were research staff members who had previously engaged in MDRT work. About eight (35%) were Mexican Americans, nine (39%) were Non-Hispanic White, and six (26%) were Asian Americans. The average age of enrolled participants was 39.5 years (range: 35–50 years). Approximately 75% of those enrolled were junior faculty, 15% were senior faculty, and 10% had recently transitioned to tenured faculty. The sample included participants from different schools/colleges at UTHSCSA and UTSA (Table 1).

Table 3

Facilitators and barriers to collaboration among MDRT members (*N* = 20)

Main categories related to the identified themes	Emergent themes	Frequency (%)
1. Facilitators to collaborations in MDRT		
Viable means of communication Agreeable team members/leader	Open and frequent communication with the team and the leader	8 (40%)
	Multiple means of communication	8 (40%)
	Building and gaining trust among members	4 (20%)
2. Conflict resolution		
	Through communication	8 (40%)
	Leader's policy	2 (10%)
	Coming to agreement "before the relationship waned"	3 (15%)
	Offering individual or group incentives	2 (10%)
	Tactics such as retreats	2 (10%)
	Conflict resolution training	2 (10%)
	Finding others to collaborate with	1 (5%)
3. Barriers to collaborations in MDRT		
Shared interest/vision among agreeable team members/leader	Finding others with complementary expertise	8 (40%)
	Different scientific background	6 (30%)
	Personality and working style differences	6 (30%)
	Finding potential collaborators in behavioural sciences	3 (15%)
	Give and take/proper attribution for work	1 (5%)
	Lack of professional respect	1 (5%)
Lack of resources	Lack of resources	2 (10%)
Perceived value of teamwork	Lack of institutional support and modest valuation of MDRT collaboration	3 (15%)

Overview of emergent themes

This section is an overview of the main themes that emerged from semi-interview responses regarding the following topics: the importance of/interest in MDRTs, team formation, team collaboration, conflict resolution, and facilitators/barriers to working in MDRTs.

Importance of MDRTs: Shared interest/vision

All participants perceived working in MDRTs as an important endeavour to advance science and improve human health. Participants who started MDRT work during graduate or postgraduate training indicated that working in MDRTs had played an instrumental role in their research practice and professional careers; senior scholars indicated that including other areas of expertise made their research proposals more competitive. One individual, expressing the importance of working in an MDRT, stated, "I think we cannot do research unless we partner with people from other disciplines." The most commonly mentioned benefits of working in MDRTs were: bridging different disciplines, building collaborative opportunities, enhancing networking, and learning from new experiences, particularly about the "culture" of collaborations. Generally, all participants acknowledged the value of such teamwork, which contributed to their shared vision.

Team formation

Participants (N = 20, all active researchers) reported a broad range of MDRT team formation experiences (Table 2). Some of the ongoing collaborations reported in this study started with researchers who knew each other or had prior interactions (N = 8, 40%), whereas others were introduced by close colleagues (N = 5, 25%). One researcher explained the benefit of "always picking people [you] know," stating, "I already got an idea of how they think about something." In some instances, individuals (N = 7, 35%) had no prior interaction with members of their MDRT; they were invited to join a team because of their expertise, such as their "understanding of the community." Others approached potential collaborators at different academic events (e.g., seminars); a few conducted a "Web search" to find expertise that would complement their own research.

All 20 researchers provided insight about the factors that promoted and hindered the formation of MDRTs (Table 2). Eleven individuals (55%) reported that having established relationships with colleagues of different expertise is important in facilitating team formation; others (N = 4, 20%) indicated finding people with shared or overlapping interests was an important aspect of forming a team. Additional factors promoting team formation included: trust (N = 2, 10%), affable relationships (e.g., people with agreeable personalities) (N = 2, 10%), and having institutional support (i.e., in terms of time and money) (N = 1, 5%). In addition, participants identified several barriers to team formation, such as: finding members with a different scientific background (N = 9, 45%), disagreeable relationships and nonsocial members (N = 4, 20%), lack of incentives to work in an MDRT (N = 3, 15%), lack of institutional support (N = 2, 10%), and time and scheduling demands (N = 2, 10%).

Collaboration in MDRTs

Open and frequent communication, particularly from the leader, was perceived as crucial for the success of team research (N = 8, 40%), as it helps facilitate the exchange of ideas: "communication is two ways, so you have to be able to deliver

and, at the same time, listen" (Table 3). One participant stated that "one of the things a chair [person] can do is to keep the fire burning in the team, as it is easy to roll back and do your own thing and act at the very minimum that you need to do." In addition, participants indicated that "regular" or "constant" communication with their team is very important. For example, one individual meets with the team "once a week; with my administrative assistant, I see her every day." Another participant stated that problems arose with the team because "we didn't have enough communication … we were not having frequent meetings." A third participant stated that "very focused but frequent" interactions from the leader are helpful in "foster[ing] better communication and collaboration." Another individual reinforced this by describing her leader's open door policy, saying, "she is very open to receiv[ing] feedback and explor[ing] ideas about how we can explore our relationships as a team."

Participants (N = 8, 40%) discussed the means of communication used among team members, stating that their teams use a combination of face-to-face, email, and phone interactions. Another important aspect of communication identified by participating researchers (N = 4, 20%) is that it builds trust among members.

Conflict resolution in MDRTs

Participants (N = 20) identified several strategies for conflict resolution (Table 3). They indicated that conflicts can be resolved through: proper communication (N = 8, 40%), the team's leadership policy (N = 2, 10%), coming to agreement "before the relation waned" (N = 3, 15%), offering incentives for the individual or team (N = 2, 10%), tactical retreats (N = 2, 10%), conflict resolution training (N = 2, 10%), and finding other collaborators (N = 1, 5%). For example, in a situation where there was conflict across departments, one individual stated, "what you try to do is to bring [in] something from which everybody can benefit from your collaboration."

Barriers to collaboration in MDRTs

Participants also discussed some of the barriers to MDRT work (N = 20) (Table 3). A common challenge faced by MDRT members (N = 8, 40%) is finding others with complementary experience as well as network outside the institution. Another cited barrier (N = 6, 30%) was having a "different scientific background" that limits effective communication—a "different language." One participant noted that "mutual understanding of key terms is very important because it can be an obstacle if they do not understand [what you say]." In addition, differences in team members' training may result in varying ways of addressing issues (e.g., "preventative" versus "curative"), therefore limiting collaborations among diverse groups of people. As one individual stated, "[d]ifferent disciplines have different points of view, and sometimes there is the challenge of trying to bring them together to reach a common goal."

Many barriers to collaboration also arise from differences in personalities (N = 6, 30%). One participant noted that many "people have not … [been] socialized for collaborative research." For instance, one participant commented that with some people "there is a lot of pride. You have the feeling that [people] are bigheaded and

have over-inflated egos. It's difficult to have a relationship with people like that. You know, the aggressiveness of some people." This is especially true when there is a power struggle and no respect among team members. Yet another participant described an instance where all the decisions "went through the study coordinator, and she kept taking powers away."

Difficulty finding potential collaborators in behavioural sciences (N = 3, 15%) and inadequate institutional support or modest valuation of MDRT collaboration (N = 3, 15%) were also considered significant barriers to collaboration. One participant highlighted the importance of fair balance between giving and taking and proper attribution for work in collaborations, as it may become a source of conflict. According to this participant, "We do a lot of things for them and we don't get much back. … I trained their students and I'm not even in the program, and what did they consider for me?"

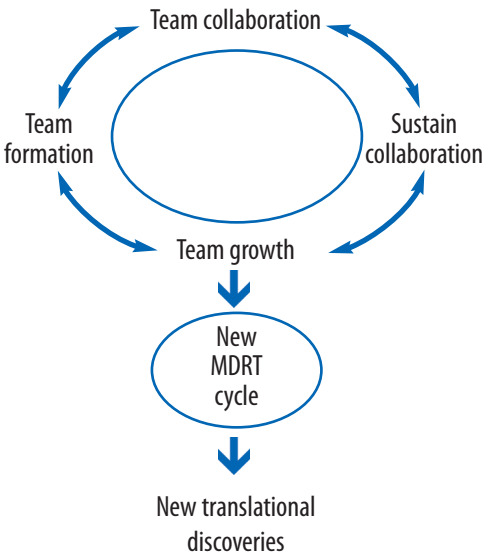
In another instance, a participant remarked that "some professions don't respect any other profession. Some professions do not respect the knowledge of another profession. There is skepticism about the contributions that other professions actually bring" and, as a result, working in collaborative teams becomes especially challenging. Furthermore, two instances of barriers arising from "professional jealousy" and "lack of trust" were described (N = 2, 10%). One interviewee explained that this complication occurs because they are being judged by their peers, but often they are competing against them. Another explained that good partnerships dissolve simply because there is not enough trust. Trust was described as something built over time and, at times, was simply a matter of trial and error.

MDRT Cycles

Several open-ended questions elicited participants' experiences working in MDRTs. Examples of these questions include: How did your team start? What happened next? What facilitated/hindered collaboration and growth of your team? What initiated the formation of a new team? Participants, specifically, senior researchers, described their experiences participating in MDRTs using four distinct stages of: 1) team formation, 2) team collaboration, 3) sustainable collaborative activities, and 4) team maturity. Each stage in a given cycle is interconnected and interdependent. A cyclical model best represents MDRT structure, function, and dynamics, as illustrated by the two-headed black arrows in Figure 1. Team formation is the first step in the

Figure 1

A model for multidisciplinary research teams cycles

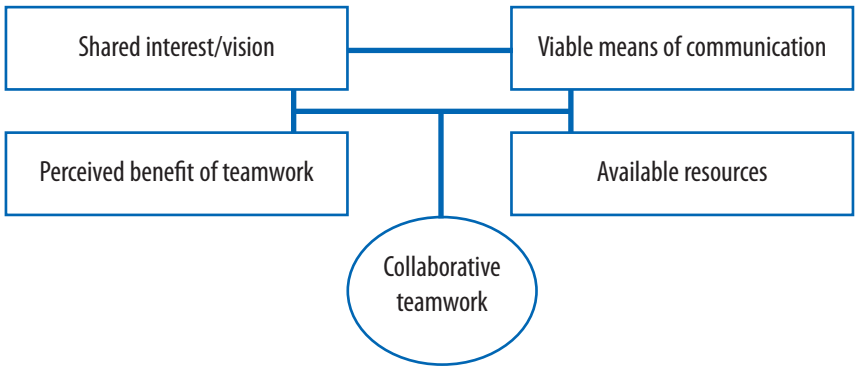


cycle, which can be initiated by stimulating interested members to take an active role in seeking collaborative teamwork. The successful cooperation and interaction among team members will lead to sustainable team structure and function, which allows the team to mature. A mature team creates a new MDRT cycle, illustrated by the smaller circle in Figure 1. Several cycles of maturing teams lead to new discoveries that can be translated to improvements in clinical practice and overall healthcare.

In addition, content analysis (see Tables 2 and 3) showed that, by and large, a successful MDRT cycle depends on the integration of four interrelated basic elements within the MDRT tract, including: 1) shared interest/vision among agreeable team leader and members, 2) viable means of communication, 3) available resources, and 4) perceived gain/benefit of teamwork (Figure 2). To improve team formation and collaboration among research members, we developed several strategies taking into consideration the important impact of these basic elements (http://iims.uthscsa.edu/novel.html). Our evolving approach is geared toward promoting translational research by enhancing collaborative teamwork efforts in three main domains: 1) content domain, to enhance shared interest and perceived benefit of teamwork, 2) process domain, to provide viable means of communication and, 3) resource domain, to provide funding (Table 4). The idea is to enable teamwork by leveraging the connectivity among these basic domains within the MDRT tract to maximize productivity and advance translational research (Figure 2).

Figure 2

Translational research advancement in collaborative teamwork (TRACT) approach



Strategies to Enhance the Work of MDRTs

This section briefly describes several strategies developed to enhance the work of MDRTs as guided by themes identified from the interview data.

Content strategy: Shared interest/vision

In the content domain, we have developed and implemented a) the Seminars in Translational Research (STRECH) strategy and b) the Translation Researcher Approach for Community Engagement (TRACE) strategy. STRECH aims to foster

Table 4

Novel approach to collaborative teamwork in translational MDRTs

Main Domain	MDRT cycle	Program designed to enhance MDRT
Content: Shared interest/vision. Perceived value of teamwork	Team formation/ collaboration	Seminars in Translational Research (STRECH)
		Translation Researcher Approach for Community Engagement (TRACE)
Process: Means of communication	Sustainable collaboration	Translation Researcher Awareness Program (TRAP) • Translation Researcher Ethical Advice on Teamwork (TREAT) forum • Personalized Advice on Collaborative Teamwork (PACT)
	Team formation and collaboration	Translation Researcher Activation Method (TRAM)
Resources: Pilot funding	Team collaboration	Consultation and Pilot Support (CAPS) in collaboration with Pilot and Collaborative Translational and Clinical Studies (PCTCS)

the development of innovative theories, approaches, and technologies in clinical and translational research. It is a collaborative project between NCTM-IIMS and UTSA. The seminars bring together investigators from the basic, clinical, and social sciences to highlight the bidirectional and multiple stages of translating scientific discoveries from the bench to the bedside and to the community. We conducted nine seminars last year and received excellent feedback from participants. Approximately 85 individuals have attended each STRECH presentation. Of those, 50% provided written evaluations regarding the importance of the topic, the speakers' styles, visual representations, and whether or not they will attend these seminars in the future. The majority of respondents (90%) indicated that the seminar topics are of high importance and that speakers' styles were very appropriate. Collecting such data allowed us to assess participants' interest in and satisfaction with these seminars to identify areas for future improvement. STRECH presentations/projects that have potential for translation to the community may participate in the Translation Researcher Approach for Community Engagement (TRACE) program. The goal of TRACE is to create and advance a multidisciplinary academic and community research enterprise that will expand the capacity for conducting cutting-edge translational research to improve health among people in South Texas. TRACE is currently in the implementation phase.

Process strategy: Provide better means of communication

Under the process domain, we have developed two main approaches: a) the Translation Researcher Activation Method (TRAM) and b) the Translation

Researcher Awareness Program (TRAP). TRAM aims to stimulate, inform, and activate investigators to search for other researchers whose work may complement their own. The ultimate goal of TRAM is to enhance collaborative efforts to foster clinical and translational research. IIMS provides access and training for several collaborative tools, such as Collexis, which is linked to both BiomedExperts and the Collexis Expert Platform for Translational Research (CPTR). These tools help researchers explore and expand their personal scientific network. Using the IIMS evaluation survey, we identified 79 researchers interested in building collaborative activities. We have emailed all interested researchers to educate them about this resource. In addition, we developed a TRAM assessment form to provide consultations about complementary collaborative needs. The TRAM strategy is still in the early stage of implementation.

TRAP's objective is to educate and advise translational research investigators about processes and contextual issues surrounding their work. TRAP provides up-to-date information about approaches to improve learning, relationships, and communication among team members. We have posted information on selected topics related to enabling the processes of MDRTs. These include topics on communication among team members, ethical issues surrounding team-based research, the leadership role in teamwork, and relationship-building skills among team members (http://iims.uthscsa.edu/novel_trap.html). We plan to update and evaluate the use of this resource by monitoring the number of hits each month.

TRAP itself is composed of two approaches: a) the Translation Researcher Ethical Advice on Teamwork (TREAT) forum and b) the Personalized Advice on Collaborative Teamwork (PACT). The goal of the TREAT forum is to provide an open platform to stimulate discussion on the contextual and ethical issues associated with conducting translational research among investigators affiliated with IIMS (e.g., UTHSCSA). TREAT encourages open debate, tackles hot topics, and features feedback and reflection among participants. The format is very interactive and follows problem-solving and solution-focused techniques to ethical concerns raised by participants. The ultimate goal is to enable the work of MDRTs by enhancing learning, rapport, and communication among team members. TREAT is a collaborative educational effort organized by both the NCTM and the ethics groups of IIMS. PACT offers personalized, one-on-one consultations with experts on issues surrounding translational research. These issues may include finding/identifying collaborators, obtaining and maintaining funds, conducting collaborative research projects, analyzing data, and submitting findings for publication. Some specific examples include "my work in multidisciplinary teams has not been valued by my supervisor; the PI published several papers without including my name; and the PI covered only 5% of my salary support—she tells me that I am not putting in enough effort?"

Resource strategy

In the resource domain, we have developed the Consultation and Pilot Support (CAPS) in collaboration with Pilot and Collaborative Translational and Clinical

Studies. The CAPS program helps investigators initiate, develop, and submit translational research projects to obtain internal and external funds. Methodological research projects spanning the continuum from laboratory studies to health services research and community engagement are encouraged and supported. Together, these activities will augment and leverage the work of MDRTs to achieve transformation in research practices.

Discussion

Understanding the structure, function and dynamics of MDRTs as they relate to translational research is an important inquiry. The science of team science is relatively new field that promotes team-based research through empirical examination of the processes by which scientific teams organize, communicate, and conduct research (http://scienceofteamscience.northwestern.edu/). Our findings showed that MDRTs operate through multiple cycles of 1) team formation, 2) team collaboration, 3) sustainable collaborative activities, and 4) team maturity. Content analysis of the interview transcripts identified four interrelated, basic elements within the MDRT tract that can leverage MDRT cycles. These basic elements include shared interest/vision among agreeable team leader and members, viable means of communication, available resources, and perceived gain/benefit of teamwork. We have developed and implemented several strategies guided by these findings to enable the work of MDRTs and translational research.

An initial barrier to teamwork would be initiating multidisciplinary collaborations with researchers who have complementary expertise. Defining complementary skills could be a challenge because finding the individuals who display them would require a thorough literature search [15]. Similarly, in our study we found that challenges to teamwork can exist before the team itself is conceptualized. To address this barrier, we have developed the Translation Researcher Activation Method. The goal of TRAM is to enable easy access to researchers' scientific profiles to help identify individuals with complementary expertise. The TRAM program offers training in several collaborative tools, such as Collexis, which is linked to both BiomedExperts and the Collexis Expert Platform for Translational Research.

Similar to previous research on inter- and cross-disciplinary work [2,16], we found that MDRTs occur when researchers from a range of disciplines independently work on the same problem with an intention eventually to combine their findings. Since investigators remain within the boundaries of their specialties, their collaboration involves the integration of different systems. Barriers related to isolation and poor communication across scientific disciplines suggest the need for strategies to promote shared or group reflection and conversation on approaches to improving collaborative teamwork [3,17]. MDRTs effectiveness stems from community structures built to facilitate the interaction of researchers, educators, and students from multiple disciplines [18]. For that reason, we have developed and initiated the Seminars in Translational Research and the Translational Researcher Approach for Community Engagement programs. To further leverage the work of MDRTs, we paid special attention to the interdependent aspects of the basic ele-

ments within the MDRT tract. For instance, the STRECH program brings together investigators from the basic, clinical, and social sciences to highlight the bidirectional and multiple stages of translating scientific discoveries from the bench to the bedside and to the community. The idea is to create the time and space for investigators to discuss and present their work to enhance interest in translational research. Investigators who come up with new ideas and wish to collect preliminary data can apply for pilot funds through our local IIMS. According to Feldman, there is a prevailing belief that academic institutions should help develop and maintain seamless collaboration, but researchers themselves feel that competitive nature of obtaining external funding and inadequate institutional support are also common barriers to successful engagement [12]. A major challenge to multidisciplinary teamwork is striking a successful balance between continuity in funding and continuity in expertise within the context of time management in a research-based university system [10]. The process of applying for and receiving grants is highly competitive, and it may interfere with the research initiative itself. Once a grant is obtained, investigators must work on a tight schedule to meet the goals of the grant, which may involve the team making compromises for the sake of time. Senior faculty members may be required to increase their university service or teaching load, which could compromise leadership in an MDRT and limit mentorship opportunities for junior team members [10]. Institutions need to provide more resources to facilitate the grant proposal processes for projects that cross disciplinary boundaries [7]. To address the issue of funding and institutional support, we have developed and implemented the Consultation and Pilot Support program, which has already awarded funding to about 20 pilot projects. Awardees are then required to attend the TREAT forums, which encourage open debate and reflection on ethical issues related to conducting translational research. The goal of TREAT is to enhance communication, relationships, and learning among team members (means of communication and perceived gain/benefit of MDRTs).

Conflict resolution, from ethical issues to time management, is a learning experience for a team [19,20]. Difficulty communicating or the inability to reap the full rewards of multidisciplinary teamwork are detriments to MDRTs. Sometimes it takes only a single disagreeable member to destroy team collaboration and cooperation, no matter how agreeable the rest of the members are [21]. The effect of conflict on a team, no matter its origin, can distract members from their task and disrupt team performance. As a result, team members' individual motivations and the team's ability to perform collectively may be reduced [22]. To help team members learn skills for conflict resolution, we have developed the Personalized Advice on Collaborative Teamwork (PACT) program. The adaptive nature of the team at the outset of the collaboration (reflected, for example, in respondents' reports of prior, positive experiences working with their MDRT) enhances team effectiveness within the MDRT, as do regular communication among research partners and a willingness to discuss and negotiate scientific disagreements and interpersonal conflicts [23,24]. Plans to assess and evaluate the success of our developed strategies are under way.

Conclusion

Our findings highlighted several opportunities and challenges in the formation, dynamics, and growth of MDRTs. We identified four basic elements within the MDRT tract that contribute to teamwork: shared interest/vision among agreeable team leader and members, viable means of communication, available resources, and perceived gain/benefit of teamwork. It is important to emphasize that effective strategies to advance teamwork should leverage the integration of these elements within the MDRT tract to achieve genuine and sustainable transformation in translational research. Our work contributes to the current efforts aimed at fostering translational research to positively affect human health.

Future studies and limitations

Future studies should be extended to include multiple time points. We included a number of interview probes designed to assess MDRT members' perceptions of team formation processes and subsequent cycles of collaboration, disagreement, and conflict resolution. However, respondents were interviewed at only one point in time, so it is important to document the temporal dynamics of MDRT processes and outcomes related to MDRT cycles. Another benefit of a longitudinal design is that it will allow for tracking possible changes in the quality of team collaboration from multidisciplinary to inter- or transdisciplinary processes and outcomes. A longitudinal research design would enable us to directly understand the circumstances that facilitate transition from MDRT to other cross-disciplinary (i.e., inter-/trans-) forms of collaboration in the science-of-team-science field. Moreover, the development of measurement criteria for distinguishing between MDRTs and other cross-disciplinary collaborative processes and outcomes remains an important issue for future research in this area.

In this analysis, we were primarily interested in obtaining an in-depth understanding of MDRT work based on individual experiences across different departments. A follow-up study including a larger sample of researchers from different academic departments is needed to generalize these findings. An additional concern is that only new strategies were developed from the researchers' responses, future analysis could include a solid evaluation and assessment of these strategies. The number of studies on this topic is extremely limited, but our findings offer a rationale and a direction for future research, as well as a theoretical basis for increasing the specificity and efficiency of researcher-targeted interventions, taking into consideration other external factors.

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Appendix 1

Selected open-ended questions

Teamwork: function, structure and dynamics	Selected open-ended questions
Characteristics of MDRTs	• When did the team come together as such? • What are the disciplines and fields of specialization represented in the team? • What are the home institutions of the team members?
Collaborative efforts	• How were you and others recruited for this particular project? • Did you know other members of the team before you started working together in this project? If yes, in what capacity? If no, how did you first meet them? • Have you worked as a member of a multidisciplinary research team before? If yes, Could you tell me about that (those) experience(s)? • How relevant do you think a multidisciplinary team approach is to your research? • In terms of your career, could you capitalize on this multidisciplinary team experience? If yes, elaborate. • How are individual and collective tasks organized in the research project? In other words, what is the division of labour in the project? • How does the team leader exercise his/her functions? • How would you rate the institutional support so far offered to the research project? Please elaborate.
Interpersonal processes	• In your experience, how important is the work of a leader in large research projects, and why? • In your view, what are the most important skills that a leader of a large research project must have? Why?
	• How frequently do you interact with other team members? With other members of your research subject network? • What are all the means you have used to communicate with other team members? • Typically, what are your exchanges about? • How often does the team leader communicate with you and in which form(s)?
Conflict resolution Barriers and facilitators for MDRT	• How are differences in experiences, background, and expertise balanced out in the project? Have any of these been the source of conflict? If so, how has it been addressed? How are agreements reached? How have individual and collective responsibilities been delineated?