Human Capital & Social Capital Determinants of in Translational Activity

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Abstract

The hope of translational programs, such as the Clinical and Translational Sciences Awards (CTSAs), is to institutionalize the production of translational outcomes, through the provision of services and educational initiatives, the different steps require different types of skills, resources and connections. While the sequential stages of the translational research from T1 to T4 are rationally linked, there are significant gaps that exist between the different stages due in a large part to such compartmentalization of medical careers and disciplinary specialization. This paper seeks to understand how human capital and social capital may affect translational activities. The paper first develops an integrated framework that makes use of human capital theory and social capital theory that contributes to the development of testable hypotheses. The paper then uses data from an annual survey of faculty for the Center for Clinical and Translational Scientists (CCTS) at the University of Illinois at Chicago (UIC) to test the hypotheses using a nested model in which the respondent is the first level and the relationship is the second level. Translational activity occurring in the relationship is the dependent variable. Findings show that interdisciplinary ties tend not to produce translational activities. Rather translational homophily, when both collaborators do translational research, is a key predicting factor. Additionally, relational closeness and resource provision predict the conduct of translational activity with collaborative relationships. Conclusions discuss implications for future research on translational science and for practice.

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Introduction

The United States health care system has been criticized for not delivering the a quality of medical care equal to the level of innovation and scientific advancements for which it is well known and respected effectively in spite of rapid scientific and technological advancements (Institute of Medicine, 2001).To address the challenges, the National Institutes of Health (NIH) has implemented Clinical and Translational Sciences Awards (CTSAs) Program to “develop treatments more efficiently and deliver them more quickly to patients” through a fundamental change in clinical and translational research (NIH, 2005; Zerhouni 2005). The program awards support services designed to enable clinical and translational research.

Despite these broad brush policy and program efforts, there is little understanding about how medical scientists perform translational activities or if there are specific skills or resources required. Scientists have expressed serious concerns about the complexity of translational processes which often seeks to integrate multiple disciplines, stakeholders (clinicians, health care providers, and patients), and objectives (Califf & Berglund, 2010). While the hope of translational programs, such as the CTSAs, is to institutionalize the production of translational outcomes through the provision of services and educational initiatives, the different steps likely require different types of skills, resources and connections. While the different steps – transfer of laboratory discoveries into new methods for diagnosis and therapy (T1), translation of discoveries into clinical practice (T2) and health practice (T3), and assessment of the impacts on health outcomes (T4) (Khoury et al., 2007; Trochim et al., 2011; Woolf, 2008) – are rationally linked, there are significant gaps that exist between the different stages due in a large part to such compartmentalization of medical careers and disciplinary specialization (Goldstein & Brown, 1997).

This paper seeks to understand how medical scientists bridge the gap in the translation of basic science discoveries into medical practice to effectively undertake translational activities. The study applies human capital theory, which recognizes the capabilities and experiences of the individual (Becker, 1964; Schultz, 1971), and social capital theory which identifies the potential resources available among ties in a network (Coleman, 1988). The framework enables the development of hypotheses about how interaction among individuals of different capacities can enable pairs or teams to close the translational gap. The paper tests hypotheses using network data collected in annual surveys of faculty for the Center for Clinical and Translational Scientists (CCTS) at the University of Illinois at Chicago (UIC) and provides a final discussion of the results.

Literature Review and Hypotheses

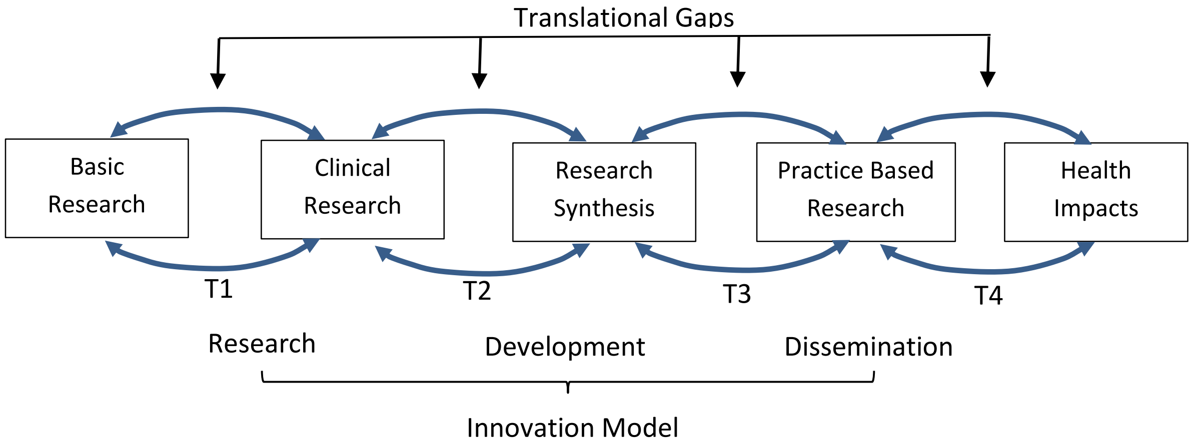
Translational processes and gaps

Translational science can be defined as: "the multidirectional and multidisciplinary integration of basic research, patient-oriented research, and population-based research, with the long-term aim of improving the health of the public" (Rubio et al., 2010). The translational process has been divided into several stages (Trochim et al., 2011; Woolf, 2008). The first stage is to transfer new understandings of disease mechanisms discovered in laboratory into new methods for diagnosis, therapy, and prevention and their first testing on humans (Stage T1). Translation of lab discoveries into the development of new methods often requires connections and shared knowledge among basic and clinical scientists. The second stage is translating medical discoveries into clinical practices through guideline development, meta-analyses, and systematic reviews (T2) (Khoury et al., 2007; Trochim et al., 2011; Woolf, 2008). The third and the fourth stages are conducted in health practice. In the third stage, evidence-based guidelines are translated into health practice (T3). T3 covers dissemination of evidence-based guidelines, integration of the interventions into the existing infrastructure, and diffusion to stakeholders (Khoury et al., 2007). The final stage is to assess the impacts of clinical guidelines on health outcomes (T4). The assessment findings are typically important for both medical science and for key stakeholders including patients, family, providers, those fiscally liable, and government agencies (Khoury et al., 2007).

There are substantial lags in translational processes (Contopoulos-Ioannidis et al., 2008) due in part to institutional and behavioral obstacles. Two of these obstacles are that medical science compartmentalizes or differentiates basic and clinical research careers and specialties (Goldstein & Brown, 1997) and that biology and medical disciplines are increasingly specialized (Albani, Colomb, & Prakken, 2010; Anger & Piquette-Miller, 2008; Califf & Berglund, 2010). Physicians who have scientific training (received a PhD) choose careers in academic setting and conduct basic research while those who work in patient-care or conduct clinical research (or patient-oriented research) are less likely to have a PhD. PhD scientists are more likely to work on basic research, while many clinical researchers also do not have sufficient basic science training or are simply required to spend more time on patient care, which can cut into time for research (Jones and Gold 2001).

Additionally, clinical research results are often not well integrated into clinical practice; physicians and other providers do not always follow evidence based guidelines (Salber, 2002) or they may not be familiar or not aware of medical guidelines applicable to their practices (Cabana et al., 1999). These factors might help cause delays in translational processes resulting in substantial deficits between what is discovered by lab science and how it impacts patients. The mechanisms that produce or reduce the gaps (or chasms as they are sometimes referred to) located between T1 and T3 have been described as "'black boxes' in which activities of translation remain vague" (Drolet and Lorenzi 2010). Figure 1 presents a summary graphic of these ideas.

Figure 1. Gaps in translational processes & innovation stages



Innovation models, human capital and social capital

Innovation theorists have developed models defining the stages of innovation that in many ways resemble the stages of a translational process (Tornatzky & Fleischer, 1990). Innovation processes generally have three stages (despite some variants): research, development and dissemination. Research produces scientific or technical knowledge. Development translates scientific knowledge into working artifacts or prototypes which are tested and evaluated. Dissemination involves moving the tested prototypes into broader use through manufacturing, packaging, distribution and marketing. The result of this process is a new product or a new service (Pavitt, 2005; Tornatzky & Fleischer, 1990). The stage model is not necessarily linear; scientific research stimulated by product development through continuous and significant feedback cycles (Kline & Rosenberg, 1986; Stokes, 1997; Tornatzky & Fleischer, 1990). The translational process is comparable to the innovation process. T1 represents the knowledge production stage, T2 the development stage, and T3 and T4 the dissemination stage. The translation process is also non-linear due to feedback effects.

Bridging the gaps across research, development, dissemination activities and outcomes can be explained using human capital and social capital theoretical perspectives (Marvel & Lumpkin, 2007; Mascitelli, 2000; Nahapiet & Ghoshal, 1998; Tsai & Ghoshal, 1998). Human capital theory recognizes the capabilities and experiences of the individual (Becker, 1994; Schultz, 1961) and social capital theory identifies the potential resources available among ties in a network (Coleman, 1988). In remainder of this section, this study discusses relevant literature related to human and social capital determinants of innovative activities and forms the rationale for several hypotheses predicting translational activities.

Human Capital

Scientific human capital is defined as "the sum of scientific and technical knowledge, skills, and resources which is embedded in an individual" (Bozeman & Corley, 2004, p. 601; Bozeman et al., 2001). It encompasses formal education, informal training, a mix of academic work experience and industrial consulting, ability to write successful grant proposals, manage complex funding streams, and mentor students (Bozeman et al., 2001). Individual skills and training are important resources that enhance competiveness of individuals and other collectives (Coleman, 1988; Gimeno et al., 1997; Marvel & Lumpkin, 2007).

Human capital required to undertake translational activity may be limited by institutional or training traditions that compartmentalize of the biomedical career into basic research or clinical research. Biomedical scientists who conduct clinical research may be less and have less available time to devote to academic research to produce journal articles (Goldstein & Brown, 1997, Jones and Gold, 1998; 2001; see also Lovejoy and Clark, 1995) and may not have the equivalent research-based education (Goldstein & Brown, 1997; Zemlo et al., 2000). Prior work has shown that clinical faculty have stronger entrepreneurial roles at the end of the research process where they are more likely to engage with industry, than their academic faculty counterparts (Louis et al. 2001). By contrast, scientists who PhDs in a medical science field may be in academic settings that require high academic productivity (Ley & Rosenberg, 2005) and greater commitment to basic science than clinical research, as compared to colleagues who do not have PhD degrees (Goldstein & Brown, 1997; Ley & Rosenberg, 2005) .

In addition, specialization in biology and clinical science has recently increased (Anger& Piquette-Miller, 2008). A broad base of medicine has been replaced with a loose confederation of specialties that focus on a single disease or organ (Goldstein & Brown, 1997; Albani, Colomb, &Prakken, 2010). Increasing specialization may not be helpful for addressing a complex medical problems which require integrated rather than fragmented approaches (Cicchetti & Toth, 2006). Both compartmentalization and specializations can cause barriers to bridging the first two translations stages. Translational researchers who have high productivity as well as scientific training may be less likely to perform a translational activity.

H1: Medical science researchers who have higher journal article productivity will be less likely to collaborate on translational activity.

H2: Medical science researchers who have greater scientific training (i.e. have received a medical PhD) will be less likely to collaborate on translational activity.

Social capital

Social capital facilitates actions of individuals and other collectives through exchange of individual human capital (Coleman, 1988, 1993; Coleman & Coleman, 1994). Individuals or groups may access resources through formal or informal relationship with others (Burt, 2009; Wall et al., 1998) and network relationships can provide resources for the good of the individuals or other collectives such as group or society (Dakhli & De Clercq, 2004). Structural characteristics of network relationships such as structural holes, strength of ties or network density have been shown to be important predictors of innovative behavior (Beckmann, 1994; Constant et al., 1996; Liberman & Wolf, 1997; Liebeskind et al., 1996; Meyer-Krahmer & Schmoch, 1998).

Social capital facilitates new forms of innovative association, plays a role of value creation (Nahapiet & Ghoshal, 1998; Tsai & Ghoshal, 1998) and has been highlighted as important source for economic performance and scientific productivity (Knack & Keefer, 1997; Lee, Wong, & Chong, 2005; Mascitelli, 2000). Within science, professional networks integrate knowledge, skills and resources in new ways that produce new scientific knowledge (Bozeman et al., 2001; Bozeman & Corley, 2004; McFadyen et al., 2009).

Interdisciplinarity

Interdisciplinary collaboration is defined as a process occurring between individuals in different disciplines that produces collective outcomes (Berger-Weger & Scheneider, 1998), and it is an important research agenda for future intellectual development in sciences (Wilson, 1988). Interdisciplinary collaboration has been found to contribute to the identification of solutions to complex problems by combining knowledge sets between disciplines (Bruce, Lyall, Tait, & Williams, 2004). Prior work on collaboration networks has pointed the importance of interdisciplinary collaboration for the conduct of translational activity and the production of translational outcomes. Translational science is described as “the multidirectional and multidisciplinary integration of basic research, patient-oriented research, and population-based research, with the long-term aim of improving the health of the public” (Rubio et al., 2010). And prior work has noted that to undertake effective translational research, scientists are likely to “utilize multi-disciplinary (experts from different scientific fields collaborate yet reside in their topic areas), inter-disciplinary (results and expertise from two or more scientific fields are synergistically combined), or trans-disciplinary approaches (disciplinary boundaries are crossed to create a holistic approach).” (Borner et al, 2010). The NIH publication, *NIH Roadmap for Medical Research: Research Teams of the Future* also stresses the importance of interdisciplinary efforts will give insights into biomedical problems (Lewin, 2010).

The team science literature has investigated the importance of interdisciplinary and multidisciplinary combinations of researchers for the conduct of translational activity and the production of translational outcomes (Falk-Krezsinski, et al. 2010; Hall 2012). Classical work provided early evidence demonstrating the importance of cross-disciplinary collaboration to addressing problems in medical research (Bearn, 1993; Kendall, 1971, Harvey, 1986). More recent evidence of the importance of interdisciplinary research in medical science is evident in studies of computer technology use in drug design (Talele et al., 2010), cross-discipline efforts to address problems related to preterm birth (Stevenson et al., 2012) and research to understand the underlying cancer mechanisms and risk factors, and advance prevention and treatment efforts (T. K. Lam, Spitz, Schully, & Khoury, 2013). While these examples and others are not directly tied to translational outcomes, the linkage between interdisciplinarity and translational outcomes seems to be expected and logical. Therefore, we offer the following hypothesis.

H3. Dyadic collaborative relationships in which researchers are from different disciplines will be more likely undertake translational activity than dyadic collaboration relationships in which researchers are from the same discipline.

Translational Homophily:

Homophily refers to the level at which two nodes have similar characteristics. Examples given in the literature include rank or position, sex, age, scientific discipline, education and race among others (McPherson et al., 2001; Monge and Contractor, 2003). Early work has shown that as homophily increases, communication becomes more effective and stimulates greater interaction (Rogers and Bhowmik 1970). Brass, et al. (1998) have also found that homophily is an important predictor of behavioral outcomes because it fosters trust and can encourage reciprocal behavior. Prior research on science collaboration has also noted that homophily is an important predictor of the structure of collaborative ties (Evans et al. 2011; Jha and Welch, 2010; Cummings and Kiesler, 2008).

Translational homophily represents a specific type of relationship in which the both collaborators in a dyadic relationship undertake translational activity. While the relationship may be interdisciplinary, it is more accurately described as being composed of two entities that are committed to the goals of translational research. Translational homophily may mean that the dyad has greater availability of translational resources than in other collaborative relationships in which one or neither of the parties undertakes translational activity. When both research partners have translational experience, they may share commitment to translational outcomes, have greater combined knowledge about translational processes, be able to communicate about translational topics, have access to a broader range of methods and approaches, or any number of other resources that enhances their willingness to engage in and provide resources that contribute to translational activity.

H4: Dyadic collaborative relationships in which both researchers conduct translational research will be more likely undertake translational activity than dyadic collaborative relationships in which one or both researchers do not conduct translational activity.

Strength of Ties

Social capital facilitates actions of individuals and other collectives through exchange of individual human capital (Coleman, 1988, 1993; Coleman & Coleman, 1994). Individuals or groups may access resources through formal or informal relationship with others (Burt, 2009;

Wall et al., 1998) and network relationships can provide resources for the good of the individuals or other collectives such as group or society (Dakhli & De Clercq, 2004). Structural characteristics such as ties strength has been shown to be an important predictor of collaborative behavior (Beckmann, 1994; Constant et al., 1996; Liberman & Wolf, 1997; Liebeskind, Oliver, Zucker, & Brewer, 1996; Meyer-Krahmer & Schmoch, 1998).

Strength of relationship has been found to have positive effects on knowledge creation in biomedical research (McFadyen & Cannella, 2004) and has been shown to be important for facilitating the interdisciplinary work that lies at the foundation of translational research (NAS 2005; Stokols 2003; Armstrong et al. 2013). For the conduct of translational activity, tie strength, as it enables access to social capital, may help bridge translational gaps existing because of career compartmentalization and discipline specialization.

Two key indicators of strong ties are close friendship and resource provision. Close friendship indicates strong ties among individuals, as opposed to acquaintance relationships (Erickson et al., 1978; Granovetter, 1973; Marsden & Campbell, 1984; Murray et al., 1981). Number of resources exchange or type of resource provision may also indicate strength of a tie (Marsden & Campbell, 1984; Su & Lee, 2012) as stronger ties are expected to provide access to potential resources (Lin, 2001). Additionally, provision of more resources among actors likely indicates high interdependence (Lazega & Pattison, 1999).

While we are not certain that strong ties lead to translational outcomes among the broad range of medical scientists, it is likely that at least within those who identify as translational scientists strength of ties will lead to translational outcomes.

H5: Translational ties that are with close friends are more likely to result in translational activity.

H6: Translational ties in which the collaborator provides more resources will be more likely to result in translational activity.

Data and Methods

The primary data was obtained from the 2010 Annual Scientific Collaboration Survey for the Center for Clinical and Translational Science (CCTS) at the University of Illinois at Chicago (UIC), which is one of the many funded Clinical and Translational Science Awards in the US. The survey respondents include UIC faculty members and non-faculty members who have ever used CCTS services.

The survey applied an ego-centric network design to explore the respondents' relationship with their collaborators, which is the global network of which individuals are members (Wasserman & Faust, 1994). The survey instrument used a series of name generator (five names possible) and name interpreter questions to collect network data. Respondents were asked five name generators to elicit names of faculty collaborators at the University of Illinois (UI), faculty collaborators at other universities, postdoctoral researcher collaborators, PhD student collaborators, and nonacademic collaborators, with whom they had worked in the past academic year. Collaboration was defined *as any teamwork designed to produce intellectual products including a research grant proposal, research study, working paper, academic conference paper, academic journal article, product development, patent application, clinical guidelines, policy report or other policy directed material, materials for public media (TV, radio or newspaper), and educational activities (courses).*

Duplicate names were automatically cleaned and a unique set of names was piped into name interpreter questions. Those questions asked about relational closeness, characteristics of collaborators, type of collaboration, and resource exchange. The data on collaborators and collaborative relationships form the basis of the network data used in the study. In addition, respondents were asked traditional set of survey questions about research productivity, outreach activity, patenting, use of translational services provided by UIC's CTSA, and demographics.

The survey was administered online posted as a webpage and completed by respondents. Individuals were invited to the webpage by email and a hard copy letter through intercampus mail. Follow-up phone calls were also made to respondents to increase the response rate. Each of individuals was provided ids and passwords. The survey took about 40 minutes to complete. The target population includes 938 CCTS users and 499 eligible non-users. Faculty respondents accounted for 590 users and 491 non-users. The final sample size was 1,437 and the response rate was 39.4%, with 565 useable responses. The final sample size used in this paper dropped to 433 due to missing data.

Dependent variables

This study focuses on three translational activities: dissemination of research results to non-academic audiences; clinical research activity, [1]and medical intervention.[2] Three measures were created from the name interpreter questions about the ways in which collaborators impacted respondents' research. The specific questions are presented in the appendix. *Dissemination* is a discrete variable is coded '1' when a collaborator helped the respondent helped his/her research to translate to a lay audience, and '0' otherwise. *New clinical research activity* is a discrete variable is coded "1" when the collaboration led to a new clinical research activity and '0' otherwise. *New intervention* indicates whether dyadic collaboration led to a new type of intervention (1=yes).

Independent variables

Within the human capital category there are two independent variables, two capturing productivity and one capturing training. *Publication productivity* is measured as the number of self-reported journal articles published between August 2009 and August 2010. Respondents have, on average, 2.20 journal publications. *Scientific training* indicates whether a respondent has a PhD degree. Approximately 54 percent of respondents have a PhD degree.

Within the social capital category there are four independent variables. *Interdisciplinary collaboration* measures whether or not both collaborators are from the same discipline, as reported by the respondent (1=yes). *Translational homophily* indicates whether or not both collaborators conduct translational researcher. Findings show that approximately 33 percent of ties are translationally homophilous. *Resource provision* is a variable that measures the number of resources provided by collaborators. Four types of resources are possible: clinical expertise, data or other inputs, access to equipment, and access to facilities. These variables were individually coded one or zero according to whether or not the respondent indicated that their named collaborator provided it in a name interpreter. These four resources were summed to give a measure that ranges from zero (no provision) to four (resource of all four types of resources). C*loseness* is coded '1' (0 otherwise) if the respondent indicated that the collaborator is a close friend. Overall, 19 percent of reported collaborative relationships are among close friends.

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[1] Defined as "research with human subjects" and covering research with human subjects, "epidemiological behavioral studies", and "outcome research and health service research" (National Institutes of Health, no date).
[2] Defined as "any examination, treatment, or other act having preventive, diagnostic, therapeutic, or rehabilitative aims and which is carried out by a physician or other health care provider" (World Health Organization, 1994).

Table 1. Descriptive statistics

Variable	N	Mean	Std.Dev.	Min	Max
Relationship level					
Translational activity					
Dissemination	1574	0.18	0.38	0	1
Clinical research activity	1529	0.18	0.39	0	1
New intervention	1529	0.13	0.33	0	1
Social capital variables					
Cross-disciplinary collaboration	1745	.43	.50	0	1
Translational homophily	1743	.33	.471	0	1
Closeness	1745	0.19	0.39	0	1
Resource Provision	1631	1.18	0.89	0	4
Controls					
Gender homophily	1441	.43	.49	0	1
UI Faculty (alter)	1803	0.41	0.49	0	1
Non-UI Faculty (alter)	1803	0.26	0.44	0	1
Post-doctorate (alter)	1803	0.12	0.33	0	1
Student (alter)	1803	0.13	0.33	0	1
Non-academics (alter)	1803	0.11	0.31	0	1
Individual level					
Human capital variables					
Productivity (publication)	429	2.20	2.72	.00	15.00
Scientific training (PhD)	423	0.54	0.50	.00	1.00
Control					
Network size	389	4.65	4.17	0	21
Professor	397	0.21	0.41	.00	1.00
Associate professor	397	0.15	0.35	.00	1.00
Assistant professor	397	0.45	0.50	.00	1.00
Post-doctorate	397	0.13	0.34	.00	1.00
Clinician	397	0.06	0.23	.00	1.00
CCTS use	433	0.40	0.49	.00	1.00
Translational researcher	382	0.55	0.50	.00	1.00
Female	347	0.54	0.50	.00	1.00

Controls

Several control variables are included in the ego level (level 2) model: network size, respondent status, and CCTS user. N*etwork size* is a measure of the total number of collaborators respondents named by the respondent in the survey. Respondent status is measured using several discrete variables indicating whether or not the respondent is a *full professor, associate professor, assistant professor, postdoc*, or *clinical faculty*. Full professor is the reference. Approximately, 21% of respondents are full professors, 15 % are associate professors, and 45% of respondents are assistant professors. The remainder are postdocs and clinicians. *CCTS use* was coded ‘1’ (‘0’, otherwise) if a respondent had ever used CCTS service. Translational researcher was coded ‘1’ if respondents had conducted translational research between August 2009 and August 2010. Female is coded ‘1’ (‘0’ if male).

Controls were also included at the relationships level: gender homophily and collaborator position. *Gender homophily* is coded ‘1’ if both collaborators are female or male. Collaborator position was measured as a set of discrete variables indicated whether the named collaborator is a *UI faculty member*, *non-UI faculty member*, *post-doctorate researcher*, or *student*. UI faculty was the reference. Twenty-six percent of collaborators are non-UI faculty members and 12 percent of alters are post-doctorate researchers.

Statistical method

The study uses multilevel mixed-effects logistic regression models to investigate the research question: How do human and social capital matter affect translational activities? A multilevel mixed-effects logistic regression model is designed to deal with hierarchical nested structure and binary outcome variables (Agresti, 2002; UCLA: Statistical Consulting Group, n.d.). This study uses data with nested structure; data at one level is not independent from data at another level. Collaborative relationships are nested within individual respondents who are each “level one” units. Collaborative relationships that the respondent reports are “level two” units. This study uses STATA 12.1 statistical packages to estimate level one and level two parameters describe the relationship between predictors and outcome variables.

Relationship level model:

(1) $Yjk = \beta 0k + \beta 1k$ (Interdisciplinary collaboration) + $\beta 2k$ (Translational homophily) + $\beta 3k$ (Closeness) + $\beta 4k$ (Resource provision) + $\beta 5k$ (non-UI Faculty-alter) + $\beta 6k$ (Post-doctorate-alter) + $\beta 7k$ (Student-alter) + $\beta 8k$ (Non-academics-alter) + $\beta 9k$ (gender homophily) + R_{jk}

Individual level model:

(2) $\beta 0k = \gamma_{00} + \gamma_{01}$ (Publication productivity)k+ γ_{02} (PhD)k + γ_{03} (Network size)k +γ_{04}(Associate professor)k+ γ_{05} (Assistant professor)k + + γ_{06} (Post-doctorate)k+ γ_{07} (Clinician) + γ_{8} (CCTS use)+ γ_{09} (Translational researcher)+ γ_{10} (Female)+U_{0k})

In the level 1 model, Y_{jk} is the observed value of the dependent variable for collaborative relationship belonging to respondent k. $\beta 0k$ is the respondent specific intercept and the nine variables are the relationship level covariates. Coefficient βxk is the associated coefficient signifying the partial effects of each variable associated with respondent k.

In the level 2 model, γ_{00} is the intercept of the level 2 model, which is the adjusted mean of translational collaborative relationship, and other ten γ coefficients indicates effects on relationship level coefficients in equation (1). U_{0k} is random error independently associated with the ego level.

A multilevel mixed-effects logistic regression model has fixed effects and random effects components. In the fixed effects component, those coefficients do not vary across group while in the coefficients of the random effects are allowed to vary across groups. In this case, the intercept β0k is designated to vary around its overall mean. The regression results include estimates of the variance of the fixed effects and the random effects components.

Findings

We constructed three multilevel estimations – dissemination, clinical activity and intervention – for two different slices of data; one for all respondents and one for only respondents who are translational researchers. Table 2 presents results from the regression models for all respondents and Table 3 presents results for translational researchers. We present the findings for all respondents before turning to the translation only respondents.

Regression estimations produced some expected and some unexpected results for the human capital hypotheses (Table 2). *Productivity* was not significantly related to any translational activity, providing no support for our first hypothesis that researchers who produced more journal articles would be less likely to conduct translational activities (H1). As expected in hypothesis two (H2), *scientific training* was negative statistical relationships with *dissemination* and *new clinical activity*. *However*, the relationship of the variable with new *intervention* was not significant. Individuals who have PhD degrees are less likely to disseminate new research and less likely to develop new clinical activity in a collaborative relationship, than those who do not. Overall, we can claim some limited support of H2.

The findings are somewhat more supportive of the social capital hypotheses. *Interdisciplinary collaboration* is not significantly related to any of the three translational activities, providing no support for the hypothesis that interdisciplinarity of dyads would increase the likelihood of translational activity (H3). On the other hand, *translational homophily* is positively and significantly related to all three translational outcomes as the study expected (H4). The result indicates that when both members of the dyad are translational researchers the collaboration is more likely to perform a new clinical activity, develop a new type of intervention, or identify a new research dissemination pathway.

Estimation findings also demonstrate support for the strength of tie hypotheses. *Closeness* with the collaborator is positively and significantly associated with *dissemination* and *new intervention* (H5), although it is not significantly associated with *new clinical activity*. The results indicate, as expected, that close relationship may provide the resources, commitment necessary to conduct translational activity. Alternatively, the close ties may facilitate communication and enable the transfer of tacit knowledge. As expected, the *resources provision* variable is also statistically significant and positive related to all three translational activities: dissemination, new clinical research, and intervention (H6). The finding indicates that relationships that commit a greater variety of resources to a collaboration may be more able to undertake different activities, such as translational work, that require multiple different types of inputs.

Table 2. Regression results (all respondents)

	Dissemination (discrete)	New clinical research activity (discrete)	New intervention (discrete)
Relationship level			
Cross-disciplinary collaboration	-0.339 (0.253)	0.263 (0.226)	-0.066 (0.274)
Translational homophily	0.910 (0.324)***	0.816 (0.286)***	0.878 (0.356)**
Closeness	0.550 (0.288)*	0.261 (0.264)	0.816 (0.276)***
Resource provision	0.935 (0.149)***	0.632 (0.130)***	0.559 (0.148)***
Gender homophily	0.087 (0.232)	-0.068 (0.209)	0.249 (0.240)
Non-UI Faculty (alter)	-0.347 (0.258)	0.135 (0.229)	0.109 (0.270)
Post-doctorate (alter)	-1.868 (0.451)***	-1.560 (0.420)***	-1.122 (0.425)***
Student (alter)	-2.746 (0.581)***	-1.296 (0.454)***	-1.036 (0.463)**
Non-academics (alter)	-1.739 (0.501)***	-0.751 (0.426)*	-0.494 (0.537)
Individual level			
Productivity (publication)	0.057 (0.080)	-0.054 (0.064)	0.055 (0.081)
Scientific Training (PhD)	-1.026 (0.451)**	-1.322 (0.368)***	-0.103 (0.484)
Network size	-0.181 (0.063)***	-0.066 (0.050)	-0.064 (0.064)
Associate professor	0.078 (0.650)	-0.236 (0.515)	-0.678 (0.670)**
Assistant professor	0.037 (0.517)	-0.202 (0.417)	-1.054 (0.531)
Post-doctorates	1.800 (0.749)**	0.146 (0.643)	-0.937 (0.818)
Clinician	0.368 (1.130)	1.104 (0.911)	-0.353 (1.258)
CCTS use	-0.586 (0.428)	1.031 (0.352)***	-0.149 (0.454)
Translational researcher	0.578 (0.486)	0.753 (0.413)**	0.087 (0.517)
Female	-0.260 (0.426)	0.532 (0.359)	-0.311 (0.463)
Constant	-1.959 (0.788)**	-3.032 (0.684)	-3.137 (0.837)

< 0.1; ** < 0.05; *** < 0.01

Translation researcher only findings (Table 3) partially support the hypotheses about the relationship between human capital and translational outcomes. *Productivity (publication)* has a negative significant relationship with *new clinical research activity*, but no significant relationship with dissemination of intervention (H1). The results indicate that translational researchers who are productive in publishing journal articles are less likely to perform new clinical research activities in the collaborative relationship. *Scientific training* also has negative statistical relationships with both *new clinical research activity* and *dissemination*, but no statistical relationship with new *intervention* (H2). Individual translational researchers who have scientific training (PhDs) are less likely to develop new research clinical activity or disseminate a new research in the collaborative relationship, compared to those who do not.

The findings also partially support social capital hypotheses. Although, *interdisciplinary collaboration* is not significantly related to any of three translational activities (H3), results show that t*ranslational homophily* continues to be positively and significantly related to all three translational activities (H4). These results indicate that when both individual and the collaborator are translational researchers the collaboration is more likely to disseminate new research to lay audiences, develop new clinical activity, and conduct a new type of intervention.

Table 3. Regression results (translational researchers only)

	Dissemination (discrete)	New clinical research activity (discrete)	New intervention (discrete)
Relationship level			
Cross-disciplinary collaboration	-0.361 (0.299)	0.239 (0.259)	-0.076 (0.348)
Translational homophily	0.844 (0.322)***	0.777 (0.281)***	0.953 (0.371)**
Closeness	0.019 (0.354)	0.321 (0.295)	0.815 (0.354)**
Resource provision	0.995 (0.181)***	0.771 (0.156)***	0.760 (0.189)***
Gender homophily	0.217 (0.272)	-0.013 (0.238)	-0.043 (0.299)
Non-UI Faculty (alter)	-0.378 (0.298)	0.362 (0.257)	0.187 (0.338)
Post-doctorate (alter)	-1.450 (0.524)***	-1.288 (0.491)***	-1.472 (0.601)**
Student (alter)	-2.524 (0.661)***	-1.137 (0.519)**	-1.125 (0.602)*
Non-academics (alter)	-1.681 (0.541)***	-1.075(0.499)**	-0.035 (0.594)
Individual level			
Productivity (publication)	-0.011 (0.100)	-0.157 (0.075)**	0.044 (0.103)
Scientific Training (PhD)	-1.098 (0.546)**	-1.124 (0.398)***	-0.013 (0.600)
Network size	-0.076 (0.080)	-0.045 (0.059)	-0.071 (0.084)
Associate professor	0.460 (0.743)	0.243 (0.531)	-0.754 (0.801)
Assistant professor	0.394 (0.607)	-0.024 (0.443)	-1.100 (0.643)
Post-doctorates	1.841 (1.142)	0.476 (0.847)	0.655 (1.157)
Clinician	0.285 (1.606)	0.022 (1.240)	-0.473 (1.796)
CCTS use	-0.864 (0.543)	0.422 (0.400)	-0.753 (0.570)
Female	-0.206 (0.535)	0.179 (0.391)	0.061 (0.587)
Constant	-1.883 (0.918)**	-1.976 (0.703)***	-3.176 (1.010)***

< 0.1; ** < 0.05; *** < 0.01

The two strength of ties variables are also positively and significantly related to at least one translational outcome providing some support for expectations. The findings show *closeness* with the collaborator has positive effects on *new intervention* but not on *dissemination* or *new clinical research activity* (H5). Also, *resources provision* by collaborators is positively related to all three translational outcomes (H6), indicating the importance of the range of inputs and assistance needed for translational work.

For control variables in both models, estimation findings show that when the other member of the collaboration dyad is a faculty member, translational activity is more likely. Additionally, in Table 2, postdocs and people with smaller collaboration networks are more likely to conduct dissemination activity, translational researchers and CCTS users are more likely to conduct new clinical activity, and associate professors are less likely than full professors to conduct new interventions.

Discussion

This study examines how human capital and social capital variables affect three types of translational activities: dissemination of research findings to lay audiences; new clinical research activity, and new medical interventions. Results provide limited support for the human capital variables and argument, but more support for the role of social capital on the conduct of translational activities. While the findings are generally in line with the innovation literature stressing the importance of human capital and social capital in innovation (Marvel & Lumpkin, 2007; Nahapiet & Ghoshal, 1998; Tsai & Ghoshal, 1998), findings also showed, surprisingly, that interdisciplinarity was not a significant contributor to translational activity. A summary of the findings and support of hypotheses is presented in Table 4.

Table 4. Summary of findings

	Variable	Hypothesis	Analysis Result			Level of support
			Dissemination (Full/TR)*	New clinical activity (Full/TR)*	New intervention (Full/TR)*	
Human capital	Productivity (publications)	-	NS/NS**	NS/ -	NS/NS	Low Support
	Scientific training (PhD)	-	- / -	- / -	NS/NS	Moderate support
Social capital	Interdisciplinary collaboration	+	NS/NS	NS/NS	NS/NS	No support
	Translational homophily	+	+ / +	+ / +	+ / +	Support
	Closeness	+	+/NS	NS/NS	+/+	Moderate support
	Resource provision	+	+ / +	+ / +	+ / +	Support

* Full = all respondents model results; TR: translational researchers only model results; ** NS = no support

The findings help to understand what factors are main contributors to the conduct of translational activities in a collaborative relationship. Shared translational expertise likely represents commitment to the conduct of translational activity, and perhaps a shared capacity or recognition of the types of resources needed to undertake translational work. Also, when researchers share a wider variety of resources they may be more able and willing to bring the range of necessary resources to the translational table. Close relationships between scientists may enable them to communicate more openly, directly and frequently, exchange tacit knowledge, and exchange resources based on trust and reciprocal understanding.

Contrary to the expectations, interdisciplinary collaboration does not have effects on translational outcomes. The measure might not adequately represent integrated efforts between disciplines and might not capture the range of interdisciplinarity evident in the collaboration (Aboelela et al., 2007). Nevertheless, it is also worthwhile considering the findings as potentially reflecting a lower need for different disciplines in a team and a greater need for a variety of skills, particularly for the T2, T3 and T4 activities. Interdisciplinary collaboration within T1 may help for basic science, but when practical knowledge is needed, other types of skill bases are required – communication insights and techniques, clinical expertise, access to communities, practical implementation insights and knowledge. These types of skills will not easily be found among basic science faculty, whether in the same discipline or in other disciplines.

Future research will enhance an understanding of the effects of human capital and social capital on translational activities. Research using longitudinal data will help better demonstrate causal mechanism of how human capital and social capital impact each other and the dependent variables. Future research also be able to address a broader range of translational activities and characteristics of translational outcomes. For example, a study may be able to differentiate different types of new clinical activities, or the level of effective dissemination, or the impact of new medical interventions. While these and other improvements may be able to address the limitations of the study, the findings are still likely to help translational science programs better understand the factors needed to build capacity to undertake translational activity.

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Appendix. Variables and Question Wording

	Variables	Questions/item wording
Relationship level		
Dependent variables: *Translational activity*	Dissemination	For the individual you named, please indicate if that person provided the following types of career support during the past academic year (August 2009 – August 2010). Helped you identify new research dissemination pathways
	Clinical research activity	For the individual you named, please indicate if that person impacted your research in the following ways. · Led to new clinical research activity · Led to new types of interventions
	New intervention	
Social capital	Cross-disciplinary collaboration	Please indicate if the individual is in your discipline (Yes=1) (reverse coded)
	Translational homophily	Please indicate if the individual does translational research (Yes=1; No=0)
	Closeness	Please indicate if the individual is a close friend (Yes=1; No=0)
	Resource Provision	For the individual you named, please indicate if that person contributed the following resources to your research activities during the past academic year · Provided clinical expertise · Provided data or other inputs · Provided access to equipment · Provided access to facilities
Control	Gender homophily	What is the gender of your collaborator? (female=1;male=0)
	UI Faculty (alter)	During the past academic year (August 2009 – August 2010), who have been your closest faculty collaborators at the University of Illinois (Chicago, Peoria, Rockford, and Urbana-Champaign)? (Yes=1; No=0)
	Non-UI Faculty (alter)	During the past academic year (August 2009 – August 2010), who have been your closest faculty collaborators at other universities/colleges? (Yes=1; No=0)
	Post-doctorate (alter)	During the past academic year (August 2009 – August 2010), who have been your closest post-doctoral collaborators? (Yes=1; No=0)
	Student (alter)	During the past academic year (August 2009 – August 2010), who have been your closest PhD student collaborators? (Yes=1; No=0)
	Non-academics (alter)	NG6 During the past academic year (August 2009 – August 2010), who have been your closest non-academic collaborators? (Yes=1; No=0)
Individual level		
	Productivity (publication)	Please indicate the number of peer reviewed journal articles (accepted or published) you have had the past academic year; August 2009 – August 2010
Human capital	Scientific training (PhD)	Which of the following degrees do you hold? (have PhD=1;do not have=0)
	Network size	Please provide both the first and last names of each collaborator Number of collaborators named by respondents
Control	Professor	

	Associate professor	Which of the following best reflects your primary status? (Tenured or tenure-track faculty; Clinical or clinical-track faculty; Research or research-track faculty; Clinician; Post-doc) (Yes=1; No=0)
	Assistant professor	
	Post-doctorate	
	Clinician	
	Translational researcher	During the past academic year (August 2009 – August 2010), did your work involve translational science or translational research? (Yes=1; No=0)
	Female	What is your gender? (Female=1;Male=0)