A Review of Multistage Research Studies Examining Social Network Dynamics Involving Dynamic Network Analysis and Response Surface Methodology: A SPIDER Approach

Po Hu[1]

Abstract

Multistage research design is gaining popularity in studies investigating social network dynamics because it has the strength to help researchers seek the most suitable decision-making process for their inquiry. This study used a SPIDER tool (Sample, Phenomenon of Interest, Design, Evaluation, Research Type) to develop a search protocol to conduct a systematic review on studies examining social network dynamics to inform optimal leadership characteristics such effectiveness and performance. Relevant research studies that used network analysis and response surface methodology were examined for their elements of research designs and findings. Results found multistage research design with the application of advanced analytical techniques such as dynamic network analysis and response surface methodology are highly recommended for such studies of social network dynamics. Advantages, disadvantages, limitations, and suggestions for future studies are also discussed.

Keywords: multistage research design, social network dynamics, dynamic network analysis, response surface methodology, SPIDER tool

การทบทวนงานวิจัยแบบหลายขั้นตอนเพื่อตรวจสอบ
พลวัตเครือข่ายสังคมที่เกี่ยวข้องกับการวิเคราะห์พลวัตเครือข่าย
และวิธีวิทยาการวิเคราะห์ผิวตอบสนอง: แนวทาง SPIDER

Po Hu[1]

บทคัดย่อ

　　การออกแบบงานวิจัยแบบหลายขั้นตอนกำลังได้รับความนิยมมากขึ้นในการศึกษาด้านการสำรวจพลวัตเครือข่ายสังคม เนื่องจากวิธีดังกล่าวมีจุดแข็งที่ช่วยให้นักวิจัยสามารถค้นหากระบวนการตัดสินใจที่ตอบข้อสงสัยได้อย่างเหมาะสม การศึกษานี้ ใช้เครื่องมือ SPIDER (Sample, Phenomenon of Interest, Design, Evaluation, Research Type) ในการพัฒนาข้อกำหนดสำหรับค้นหาโดยใช้การทบทวนวรรณกรรมอย่างเป็นระบบด้านการตรวจสอบพลวัตเครือข่ายสังคม สำหรับรายงานความเหมาะสมของลักษณะความเป็นผู้นำ ได้แก่ ประสิทธิผล และประสิทธิภาพ ซึ่งนำงานวิจัยที่เกี่ยวข้องกับการวิเคราะห์พลวัตเครือข่าย และวิธีวิทยาการวิเคราะห์ผิวตอบสนอง มาพิจารณาองค์ประกอบของการออกแบบงานวิจัยและผลการวิจัย ผลการศึกษาพบว่า การออกแบบงานวิจัยแบบหลายขั้นตอนที่ใช้แอพพลิเคชันของเทคนิคการวิเคราะห์ขั้นสูง เช่น การวิเคราะห์พลวัตเครือข่าย และวิธีวิทยาการวิเคราะห์ผิวตอบสนอง ควรนำมาใช้สำหรับการศึกษาพลวัตเครือข่ายสังคมเป็นอย่างยิ่ง นอกจากนี้ ยังอภิปรายถึงข้อดี ข้อเสีย ข้อจำกัด และข้อเสนอแนะสำหรับการวิจัยครั้งต่อไป

คำสำคัญ: การออกแบบงานวิจัยแบบหลายขั้นตอน, พลวัตเครือข่ายสังคม, การวิเคราะห์พลวัตเครือข่าย, วิธีวิทยาการวิเคราะห์ผิวตอบสนอง, เครื่องมือ SPIDER

[1] ผู้รับผิดชอบบทความหลัก ผู้ช่วยศาสตราจารย์ ดร. สาขาอุดมศึกษา ภาควิชาจิตวิทยาการศึกษาและการแนะแนว มหาวิทยาลัยเนแบรสกา เคียร์นีย์
อีเมล: hup2@unk.edu

Introduction

A multistage design is one in which research design is conducted sequentially with two or more stages to follow the logic of the research architect and to seek the most suitable decision-making process to investigate its research questions.

The multistage research design emerged from an interdisciplinary origin. Over the past decade, it has burgeoned into popularity spanning science and engineering (Altiparmak et al., 2009; Hamdy et al., 2013; Syarif et al., 2002), medical and health science (Boeree et al., 2017; Cudkowicz et al., 2014; Rothman et al., 2010; Wason & Jaki, 2012), business and economics (De Bruyn & Lilien, 2008; Fu & Lu, 2012; Nickel et al., 2012; Sheremeta, 2010), process, supply chain, and operational research (Ivanov et al., 2014; Lucia et al., 2013; Wu & Chang, 2012; Wu & Chuang, 2010). Multistage research design is gaining popularity primarily because conventional single-stage design cannot adequately address increasingly complex research issues, whereas multistage design has the advantage to help researchers seek the best suitable decision-making process for their research

Related Concepts: Social Network Dynamics, Dynamic Network Analysis, and Response Surface Methodology

Social network dynamics (SND) are buzzwords in today's world. It is almost impossible to give a conclusive definition of social network dynamics, given the ever-changing nature of human interactions in our increasingly socially connected world. For this study, social network dynamics (SND) are defined as those structures, processes, outcomes, ties, relationships, and interactions between socially connected actors such as individuals and organizations. Studies of social network dynamics focus on investigating "patterns and regularities in relationships among interacting units" (Wasserman & Faust, 1994, p. 3). In recent years, social network studies have become popular in our increasingly connected social network environment, just like the one we are living in today.

Network theory, which "refers to the mechanisms and processes that interact with network structures to yield certain outcomes for individuals and groups" (Borgatti & Halgin, 2011, p. 1168), explains the theoretical perspective of social network research and guides the studies of social network dynamics particularly those in complex organizational settings. Dynamic network analysis, or DNA, is a method of examining how networks interact. Dynamic network analysis is defined as a simulation that "reflects a plurality of node types such as people, organizations, resources and tasks (multi-mode), various types of connections among any two nodes (multi-plex), attributes of both nodes and edges (rich data), and data over time (dynamic)" (Carley et al., 2007, p. 1325). Dynamic network analysis (DNA) is the primary method for analyzing dynamic network interactions.

Response surface methodology, or RSM, is a type of design of experiments (DOE) statistical methodology. Response surface methodology (RSM) is a method defined as "a

collection of statistical techniques useful for developing, improving, and optimizing processes" (Carley et al., 2004, p. 1; Myers et al., 2016, p. 1). Response surface methodology is often used to predict responses (outcomes) as a function of multiple controllable factors (Anderson & Whitcomb, 2005) and is argued to "offer statistical design of experiment tools that lead to peak processing performance" (Anderson & Whitcomb, 2005, p. 1). Response surface methodology (RSM) is a preferable method to analyze conditions leading to optimal performance and is widely used for "exploring ... optimum operating conditions across combinations of experimental methods" (Length, 2009, p. 1).

Because of complex relationships embedded in social networks, complex interacting units that social network dynamics often must deal with, and our never-stopped aspiration to achieve optimal performance, the multistage research design involving dynamic network analysis (DNA) and response surface methodology (RSM) is considered as an ideal model for such studies examining social network dynamics in complex organizational settings.

Rather than broadly synthesizing multistage research studies examining social network dynamics, the purpose of this study is to specifically focus on conducting a systematic review of multistage research studies using dynamic network analysis (DNA) and response surface methodology (RSM) to inform optimal leadership characteristics such as effectiveness and performance, and to present scholars of research methodology an opportunity to see such examples. For this reason, the author of this study specifically asked one research question: What are the examples of multistage research studies examining social network dynamics using dynamic network analysis (DNA) and response surface methodology (RSM) to inform optimal leadership characteristics such as effectiveness and performance of education and business organizations in the United States? To answer this question, the author adopted a SPIDER synthesis method to conduct a systematic review on relevant studies in this study.

Methods

SPIDER

A SPIDER tool was deployed in this paper to carry out a systematic review of multistage research studies examining social network dynamics using dynamic network analysis (DNA) and response surface methodology (RSM) to inform optimal leadership characteristics of education and business organizations in the United States. The SPIDER tool was originally developed from a PICO tool in evidence-based health science field to support incorporating the synthesis of qualitative research into systematic reviews (Cooke et al., 2012). The SPIDER method, which developed using the popular PICO method as a starting point, has expanded to incorporate effective search strategies of qualitative, quantitative, and mixed- methods research (Cooke et al., 2012). Compared with the PICO tool (Population/Patient, Intervention, Comparison, and Outcome) (Richardson et al., 1995), the SPIDER tool (Sample, Phenomenon of Interest, Design, Evaluation, and Research Type) (Cooke et al., 2012) focuses less on

interventions and more on study designs, and samples rather than populations/patients. Both the PICO and the SPIDER tools are popular methods in conducting a systematic review. Neither tool is better than the other. However, because of this study's emphasis on examining multistage research designs involving dynamic network analysis (DNA) and response surface methodology (RSM) techniques, the SPIDER tool is determined as a more suitable approach to address the qualitative research question raised above in the study.

Search Strategy

Studies eligible for inclusion in this review were those that examined social network dynamics using dynamic network analysis (DNA) and surface response methodology (RSM) as the multistage research design to inform optimal leadership characteristics such as effectiveness and performance in education and business organizations. A search strategy was developed to achieve this goal using the SPIDER tool. Since this study is more focused on research designs and less on interventions and populations, search terms "dynamic network analysis" and or "response surface methodology" in the title, abstract, and or keywords were used in a top leadership journal (The Leadership Quarterly) to identify published journal articles and in ProQuest Dissertations and Theses Global database for unpublished dissertations and theses by September 30, 2020. It included quantitative, qualitative, and mix-methods research types. The search initially generated ten hits in The Leadership Quarterly and thirty-eight hits in ProQuest databases after removing reductions. A further review of the abstract and the full text by the researcher found two published journal articles in The Leadership Quarterly and three unpublished dissertations in ProQuest that met the searching criteria, in which studies examined social network dynamics using both network analysis (DNA) and response surface methodology (RSM) to investigate optimal leadership characteristics such as effectiveness and performance of education and business organizations in the United States. These five studies were put together for later analysis and discussion because their eligibility for inclusion met the searching protocol outlined in the study.

Results and Discussions

A content analysis was conducted to specifically examine elements of research designs and findings of the studies that used network analysis and or response surface methodology studying social network dynamics to inform optimal leadership characteristics such as effectiveness and performance in education and business settings. A systematic review of such designs and their elements made a case for recommending the use of the multistage research design for future studies examining social network dynamics to inform optimal leadership characteristics such as effectiveness and performance. The results are presented in Table 1.

Table 1 *Multistage research studies examining social network dynamics using dynamic network analysis and response surface methodology*

	Shanock et al. (2010)	Braddy et al. (2014)	Marion et al. (2016)	Stuart (2016)	Jiang (2017)	Hu (2018)
Network Boundary	Bounded	Unbounded, large scale leadership development program participants from many different organizations, and their direct reports, peers, supervisors	Bounded, all professional personnel in an elementary school	Bounded, all employees in a university enrollment management system	Bounded, all professional personnel in ten elementary schools in a school district	Bounded, all professional employees in an international education system at a top research university
Network Types	Emotional network	Task (Advice), relations (social), and career networks	Advice, social, and trust networks	Advice, social, and trust networks	Advice, social, and trust networks	Advice, social, and trust networks
Level of Network Measures	Agent-level	Multi-level	Agent-level	Agent-level	Agent-level	Agent-level
Data Analysis Procedures	Polynomial Regression and Response Surface Methodology	Confirmatory Factor Analysis, Random Coefficient Modeling via Hierarchical Linear Modeling, Relative Weight Analysis, Polynomial Regression, and Response Surface Methodology	Qualitative Analysis, Dynamic Network Analysis, and Response Surface Methodology	Qualitative Analysis, Dynamic Network Analysis, and Response Surface Methodology	Dynamic Network Analysis, Hierarchical Linear Modeling, Lenth's Analysis, Response Surface Methodology, and Multiple Regression	Dynamic Network Analysis, Response Surface Methodology, and Multiple Regression
Outcome Measure	Employee's emotional attachment to the organization – Affective commitment	Career derailment potential	Network effectiveness – Task accuracy	Information flow - Speed	Teacher effect on student test scores	Organizational performance – Network effectiveness
Significant Input Measures – Network Measures	Perceived supervisor support, perceived organizational support	Self- (matter least) direct report, peer (matter most), supervisor ratings of leader behaviors	Informal leadership – closeness centrality, clique engagement – clustering coefficient	Social capital – resource capability	Centrality, advice network, social capital	Social capital – hub centrality

Shanock et al. (2010) were among the early organizational science and psychological behavior researchers who introduced polynomial regression (PR) with response surface methodology (RSM), which was first developed in science, engineering, technology, and an industrial world, into the research of social network dynamics in organizational settings. They contended that the approach (polynomial regression with response surface analysis) "allows researchers to examine the extent to which combinations of two predictor variables relate to an outcome variable, particularly in the case when the discrepancy (difference) between the two predictor variables is a central consideration" (Shanock et al., 2010, p. 543). Their study was not identified through the initial search process because they conducted their research in a hypothetical setting arguing for the use of polynomial regression with response surface methodology and did not carry out dynamic network analysis (no actual interactions to analyze within a hypothetical setting). However, because of its relevance of their research design and their pioneer status of applying such design to the field, Shanock et al. (2010) study was included in the final six studies for content analysis and discussion. They applied an example in a hypothetical setting through a bounded social- emotional network, that used perceived supervisor support (PSS) and perceived organizational support (POS) as two predictor variables, to produce the optimal level of affective commitment (AC) as an outcome variable. Shanock et al. (2010) found the optimal level (either positive curvature or negative curvature) of employee's emotional attachment to the organization – affective commitment (AC) - can be experimented by the functions of the level of discrepancy between perceived supervisor support (PSS) and perceived organizational support (POS) using polynomial regression with response surface methodology.

Braddy et al. (2014, p. 373) examined "how the relationships between task-orientated and relationship-orientated leader behaviors and career derailment potential vary by observer perspective". They collected data from 966 leaders from many different business organizations and multiple business sectors who attended a leadership development program, plus thousands of their direct reports, peers, and supervisors (Braddy et al., 2014). It was a large- scale unbounded social network in their study. They collected data on independent measures (task- orientated leader behaviors and relations- oriented leader behaviors) and dependent measure (career derailment potential) in their network analysis. Their study applied confirmatory factor analysis (CFA), random coefficient modeling (RCM) via hierarchical linear modeling (HLM), relative weight analysis (RWA), polynomial regression (PR) with response surface methodology (RSM) as analytical techniques. Braddy et al. (2014, p. 373) found that through RCM, "self-, direct report, peer, and supervisor ratings of leader behaviors differ and are associated with career derailment potential." Their "RWA results indicate that self-ratings matter the least, whereas peer ratings of leader behaviors typically matter the most in predicting career derailment potential" (Braddy et al., 2014, p. 373). Polynomial regression with response surface methods "indicate that career derailment potential is lowest when self-

ratings are lower than other ratings of leader behaviors and/or when self–other ratings converge on higher, rather than lower, ratings of leader behaviors" (Braddy et al., 2014, p. 273).

Marion et al. (2016) examined three social network dynamics (informal leadership, informational flow, and clique engagement) that, according to the collective perspective of complexity theory and network theory, influence a network's capacity to perform (network effectiveness). They collected data on advice, social, and trust networks from 71 full-time teachers, administrators, and staff from an elementary school to calculate agent-level measures for each participant. They used multistage research design with mixed-methods and applied qualitative analysis, dynamic network analysis (DNA), and response surface methodology (RSM) as their analytical techniques. Marion et al. (2016) found informal leadership (closeness centrality) had a significant effect on network effectiveness (task accuracy) and clique engagement (clustering coefficient) had a nonlinear effect on network effectiveness. Information flow (speed) had no direct significant effect on network effectiveness (task accuracy), but indirectly "cliques can absorb large amount of information flow (vitality) thus promoting stable productivity levels" (Marion et al., 2016, p. 242). Finally, they noted the broad plateau of outcomes "supports the nonlinear stability proposition" (Marion et al., 2016, p. 256) that "collective, information-processing adaptability fosters stable productivity plateaus that absorb unpredictable demands" (Marion et al., 2016, p. 242).

Stuart (2016) investigated how three independent network measures (adaptive leadership, social capital, and clique engagement) can enable and produce a dependent measure (information flow) for a sustainable enrollment management (EM) system. He collected data on advice, social, and trust networks from 20 full-time professional employees working in a university's enrollment management system and calculated agent-level network measures for each participant in a bounded network. He used multistage mixed-methods research design and applied qualitative analysis, dynamic network analysis (DNA), and response surface methodology (RSM) as analytical techniques in his study. Stuart (2016, p. 92) found "the greatest stability in information flow" when "resource capability is held at a constant high level while clustering coefficient and closeness centrality are at average levels." This meant that "resource capability was the main factor influencing the sustainable movement of information" and "clustering has no significant impact" (Stuart, 2016, p. 92). Stuart (2016) reported his finding on the clustering coefficient differed from that of Marion et al. (2016) where the clustering coefficient has a nonlinear effect on task accuracy. This might be explained by the fact that the dependent measure for Marion et al. (2016)'s research was task accuracy and not average speed, however in Stuart's (2016, p.93) study, "speed was the dependent measure."

Jiang (2017) explored the relationship between teacher effect on student test scores (dependent measure) and three social network dynamics – information flow, informal

leadership, and social capital (independent measures) with perspectives from complexity and network theories. She and a group of network researchers collected data on advice, social, and trust networks from 563 professional personnel from ten elementary schools in a school district to calculate agent-level network measures for each participant in a bounded network. In multiple stages, she applied dynamic network analysis (DNA), hierarchical linear modeling (HLM), Lenth's analysis, and response surface methodology (RSM) as analytical techniques. The original 87 agent-level measures generated by DNA were reduced to 3 selected subsets of networks, that actively impact the dependent measure through Lenth's Analysis, which were used as independent variables in RSM analyses. Jiang (2017) used hierarchical linear modeling (HLM) with the best linear unbiased predictors (BLUPs) technique to generate dependent variable - teacher effect on student test scores. She found teacher's network measures have complex linear, curvilinear, and interactive effects on student test scores (Jiang, 2017). "In particular, central position in the advice network and bridging position in the trust networks exerted the most influence with multiple significant measures on more than one subject and both linear and curvilinear effects" (Jiang, 2017, p. 87).

Hu (2018) investigated how measures of engagement in complex social network dynamics (informal leadership, clique engagement, and social capital as independent network measures) affect organizational performance (as a dependent measure). He collected data on advice, social, and trust networks from 27 full-time professional employees working in an international education system at a top research university and calculated agent-level network measures for each participant in a bounded network. In a multistage research design, he conducted dynamic network analysis (DNA), response surface methodology (RSM), and multiple regression as his analytical procedures. Hu (2018, p. 130) found that "social capital (hub centrality) had a significant effect on organizational performance (task accuracy) … Clique engagement (clustering coefficient) appeared to have a weak curvilinear effect… At the same time, social capital (hub centrality) appeared to have a moderately pronounced curvilinear effect on organizational performance." Using response surface methodology (RSM), Hu (2018, p. 130-131) further reported that "the optimal level of organizational performance was achieved when social capital is at its maximum value regardless of the conditions of the clique engagement and informal leadership", and therefore he contended "social capital appeared to be the dominant factor influencing organizational performance."

Conclusions, Limitations, and Suggestions for Future Studies

The multistage research design, with the application of advanced analytical techniques such as dynamic network analysis (DNA) and response surface methodology (RSM), is gaining popularity in studies of social network dynamics to inform optimal leadership characteristics such as effectiveness and performance. This systematic review used a protocol developed from the SPIDER tool of six relevant studies that involved network analysis and response

surface methodology to examine social network dynamics in complex organizational settings. They showed examples for adopting such a multistage research design involving dynamic network analysis and response surface methodology in similar areas in future studies.

It is worth noting that the multistage research design is different from the mixed-methods research design and multistage sampling technique. Mixed-methods design is a research design that "collects and analyzes both qualitative and quantitative data rigorously in response to research questions and hypotheses, integrates (or mixes or combines) the two forms of data and their results, organizes these procedures into specific research designs that provide the logic and procedures for conducting the study, and frames these procedures within theory and philosophy" (Creswell & Clark, 2017, p. 5). Mixed-methods research most likely adopts a multistage research design when the research is completed in two or more distinctive stages. However, a multistage research design can be conducted in mixed-methods format, but not necessarily has to be mixed. Notably, only two studies (Marion et al., 2016; Stuart, 2016) which were reviewed in this paper happened to be using a mixed-methods sequential exploratory design, and the other four studies only used multiple quantitative analytical techniques in different stages.

A multistage sample is a survey sampling technique "in which sampling is done sequentially across two or more hierarchical levels" (Battaglia, 2008, p. 493) and it means taking a series of (random) samples in a sequence of stages until desired small areas have been chosen (Rahi, 2017; Taherdoost, 2016). Multistage research design studying social network dynamics can be using a multistage sampling technique, but not necessarily a requirement. All six studies identified in this review only used one sample and did not use a multistage sample technique.

Advantages of multistage research design examining social network dynamics involving dynamic network analysis and response surface methodology include providing a new approach analyzing social network from a dynamic perspective, presenting the network dynamics using a powerful visualization tool (DNA), and providing an opportunity to produce the optimal outcome by simulation through response surface methodology (RSM). Another advantage of such a multistage research design is its flexibility and versatility. The multistage research design involving dynamic network analysis and response surface methodology can be adapted to be used in many different topics and fields tailored to different research needs. It also can be very versatile so that researchers can choose to add, remove, or change different analytical techniques or procedures according to their specific needs. For example, two studies reviewed in this paper adopted the multistage mixed-methods design and the rest of the four studies adopted multistage quantitative design. More than half of the studies reviewed in this paper used three or more analytical techniques in their data analysis procedures tailored to their needs. Such flexible and versatile design allows a new approach to analyzing social network dynamics in complex organizational settings. Marion et al. (2016) study was one of

the first studies using dynamic network analysis and response surface methodology to analyze social network dynamics in school district settings. Stuart (2016) was one of the first such studies in analyzing the enrollment management system in a university setting. Hu (2018) was a pioneer in analyzing international education programs and leadership of senior international officer in the field of higher education. Disadvantages of such multistage research design are that it involves complexity in planning and carrying out the design, and it requires more resources and procedures to get it accomplished.

One seemingly limitation is the use of a single organization (site) in the dynamic network analysis and response surface methodology instead of multiple organizations (sites). It also limits interactions inside of the organization and excludes connections outside the organization. Every organization and social network dynamics are different. Social network dynamics observed at one organization are limited to that organization and have limited generalization ability to other organizations. Future research should point to a direction of conducting further studies at multiple organizations (sites) and providing more empirical evidence to support such a design.

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