Modeling the Dynamic Aspects of Team Diversity

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A Comparison of System Dynamics and Agent-based Modeling

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Abstract

Empirical studies investigate the effects of diversity on creativity, innovativeness, and performance in teams. The results of those studies show evidence of contradicting effects of diversity, dynamic change over time, and nonlinear behavior of diversity attributes. Empirical studies might not be able to capture those aspects in whole, therefore, we suggest to use simulation as a complementary method to study the effects of diversity in teams.

In this paper we start by a brief literature review, listing and categorizing the effects of diversity on creativity, innovativeness, and performance in teams. We than discuss if and how System Dynamics and agent-based modeling are able to represent the complex, dynamic, and nonlinear effects of team diversity. We show the main focus of each simulation method as well as advantages and disadvantages with respect to this problem.

This paper provides researchers with some guidance regarding which simulation method – System Dynamics or agent-based modeling – to choose when investigating a specific research question in the field of team diversity.

Introduction

Diversity or heterogeneity is the variation of people within a group (Milliken, Martins 1996; Gebert et al. 2006). Diversity can refer to many different attributes, for example gender, cultural values, education, and expertise. Diversity research in teams is mainly considered important in new product development teams and in top management teams (Tilebein, Stolarski 2009). Research attests the creativity, innovativeness, and performance of those teams to have a great influence on the performance of an organization (Hambrick, Mason 1984; Paulus 2000; Lovelace et al. 2001; Gebert et al. 2006 and Hambrick 2007).

Empirical studies show seemingly contradicting effects of diversity on the creativity, innovativeness and performance of teams: On the one hand, diverse team members have a wider range of perspectives, more available information, and thus a higher capacity for absorbing and processing information (Milliken, Martins 1996; Amabile 1998 and Gebert et al. 2006). Diversity in teams can also lead to a higher quality and quantity of ideas, solutions, and products (Bunduchi 2009). Therefore diversity can be a resource for team creativity, innovation, and performance. On the other hand, diversity in teams can lead to unwanted conflicts and communication barriers between team members, hindering effective team work (Ancona, Caldwell 1992; Lovelace et al. 2001; Gebert et al. 2006). Thus, diversity can be a risk for creativity, innovativeness, and performance in teams.

Additionally, those effects have a dynamic aspect, changing over the time a team works together (Perry-Smith, Shalley 2003). The positive and negative effects of diversity lessen, improving communication and conflict induced problems but also reducing the creative potential of diversity (Perry-Smith, Shalley 2003). There is also some evidence pointing to nonlinear behavior of some diversity attributes (Lau und Murnighan 1998 and Chi et al. 2009).

With effective diversity management, organizations can obtain the positive effects of diversity, while at the same time minimizing the negative outcomes. Diversity can become a driver for innovation and help strengthen organizations. Yet, empirical data on how to get diversity in teams to work is still limited. (Guillaume et al. 2013). Existing empirical studies examining these correlations are mostly cross-sectional and as such unable to capture the complex, dynamic, and nonlinear nature of diversity effects (Kreidler, Tilebein 2013). We

propose that simulation can offer a complementary method for examining and investigating effects of diversity in teams. In this paper we give a first step towards using simulation for diversity effects in teams by categorizing diversity effects on creativity, innovativeness, and performance. We examine, if and how System Dynamics and agent-based modeling are able to capture the complex, dynamic, and nonlinear behavior of diversity in teams. By doing so, we give researchers a guideline, which of the two simulation methods might be better suited for modeling a specific problem in the wide area of diversity research in teams.

This paper is organized as follows: We start by categorizing diversity and its effects on creativity, innovativeness, and performance in teams. We then take a closer look at the two simulation methods System Dynamics and agent-based modeling. We discuss if those methods are able to capture the complex team structures while properly depicting the contradictory, dynamic, and nonlinear effects of diversity. Based on this, we then elaborate on the strength and weaknesses of both methods with regard to the effects of diversity in teams.

Diversity in Teams

The dimension of *demographic diversity* describes attributes most of which are rather easily identified and quantified, e.g. gender, age, ethnicity, and nationality. Attributes which fall under the dimension of *cognitive diversity* are less identifiable and quantifiable. The cognitive attributes can be further dived into the subcategories *values, knowledge and abilities,* and *cohort memberships.* The subcategory *values* encompass for example attributes like personality, cultural values, and socioeconomic backgrounds. *Knowledge and abilities* refers to attributes such as functional or educational background, areas of expertise, and work experience. A *cohort membership* describes firm or team membership, or tenure as well as hierarchy level. (Milliken, Martins 1996)

Within teams cognitive diversity can have two seemingly contradictory results (Stolarski, Tilebein 2009; Guillaume et al. 2013 and Kreidler, Tilebein 2013). On one hand, diversity can lead to a wider spectrum of knowledge, abilities, and experience that can help a team to solve problems, have a higher creativity, and strengthen its innovative capability. On the other hand, diversity can obstruct communication between team members and can result in conflicts hampering or hindering team work.

Empirical studies show that the negative and positive effects of team diversity evolve dynamically. For instance, mental models of diverse team members assimilate over the time a team works together (Perry-Smith, Shalley 2003). Therefore, the negative effects of diversity lessen over time, while the creative potential also declines. Additionally, studies show that the behavior of diversity effects might be nonlinear (Chi et al. 2009). For example, (Chi et al. 2009) found a U-shaped relation between organizational tenure diversity and team innovation. Also, the emergence of subgroups and fault lines is more likely in teams with moderate diversity than in teams with low or high diversity (Lau, Murnighan 1998).

Summarizing the effects of diversity in teams from literature, three major findings occur:

1. *Contradictory Results:* Diversity can be both helpful and harmful to the innovation capability and creative performance of a team (Stolarski, Tilebein 2009 and Kreidler, Tilebein 2013).
2. *Dynamic Behavior:* The effects of diversity on team innovativeness can change over the time a team works together (Perry-Smith, Shalley 2003).
3. *Nonlinear Effects:* Diversity attributes can affect team innovativeness in a nonlinear way (Chi et al. 2009).

Categorization of Diversity Effects

Through the wide spectrum of knowledge, experience, and individual abilities, a diverse team is allegedly better able to develop innovative ideas and solutions (Milliken, Martins 1996 and Gebert et al. 2006). At the same time, however, diversity can make communication within teams more difficult and can result in undesired conflicts between team members (Gebert et al. 2006).

The effects of diversity on creativity, innovativeness, and performance of team work can be divided into two categories: direct effects and indirect effects as a result of conflict, communication, or affective consequences. In the following section we explain the mentioned categories and effects.

*Creativity***:** Through a wider range of perspectives diversity in teams can lead to higher quality and quantity of ideas, thus increasing a team's creativity (Akgün et al. 2008 and Bunduchi 2009). However, conflicts and communication barriers can complicate or hamper cooperation

so that a team cannot benefit from the creative potential of diversity (Gebert et al. 2006 and Kreidler, Tilebein 2013).

*Innovation***:** The effect of diversity on innovation is parallel to the effects on creativity (Ancona, Caldwell 1992 and West 2002). Studies also examine the influence of diversity on degree of radicalness of innovation (Cabrales et al. 2008).

*Performance***:** Empirical studies show positive, negative or neutral influences of diversity on performance (Leenders et al. 2003; Kratzer et al. 2004; Homberg, Bui 2013 and Blindenbach-Driessen 2015). Performance can refer to creative performance of teams, new product performance, or organizational performance (Leenders et al. 2007; Homberg, Bui 2013 and Chen et al. 2015).

Creativity, innovativeness, and performance are difficult to measure directly. Therefore, studies often use the novelty, quality, or quantity of ideas, solutions or products as proxies (Akgün et al. 2008 and Bunduchi 2009).

Diversity in teams can lead to conflicts and communication barriers, which can hamper or hinder team work (Gebert et al. 2006). Also affective consequences influence the diversity effects on creativity, innovativeness, and performance (Milliken, Martins 1996).

Team Intelligence: Diversity of team members can lead to a better absorption and processing of information in a team, as well as to a higher availability and wider range of information and knowledge.

*Conflicts***:** High diversity in teams can lead to various conflicts between team members (Gebert et al. 2006). However, not all conflicts hamper cooperation. Relationship conflicts, value conflicts, and goal conflicts can easily transfer to an emotional level between team members and negatively affect team work (Jehn, Mannix 2001; Jehn, Bezrukova 2004 and Gebert et al. 2006). Yet, task conflicts can lead to new ideas and solutions, if they can be separated from emotional conflicts (Gebert et al. 2006 and Kreidler, Tilebein 2013).

Fault lines between subgroups in teams are more likely to appear in moderately diverse teams than in teams with low or high diversity (Lau, Murnighan 1998). Subgroups and fault lines can lead to unwanted conflicts, which in turn harm cooperation within a team (Jehn et al. 2008, p. 150).

Communication: (Synergistic) communication is decisive for cooperation within a team (Gebert et al. 2006). Communication barriers within a team, as a result of conflicts, emotional tensions, or different subject jargon, reduce its innovative potential (Gebert et al. 2006 and Kreidler, Tilebein 2013). Studies also describe the influence of external communication on the creativity, innovativeness, and performance of teams as being important (Ancona, Caldwell 1992 and Vissers, Dankbaar 2002).

*Affective Consequences***:** The affective effects of diversity can include satisfaction with work conditions, identification with the group, or motivation. Trust in other team members and the management/team leader as well as group social integration play an important role in good teamwork. Diversity and how it is perceived within a team or an organization can have an effect on those affective factors, which in turn influence the work outcome of teams. (Milliken, Martins 1996)

Additionally, *environmental conditions* can affect the creativity, innovativeness, and performance of teams. Studies have identified conditions like team size, organizational support, team-oriented human resource practices, a psychologically safe communication environment, or encouragement to take risks (Amabile 1998; Sethi et al. 2001; Vissers, Dankbaar 2002; Gibson, Gibbs 2006 and Chi et al. 2009).

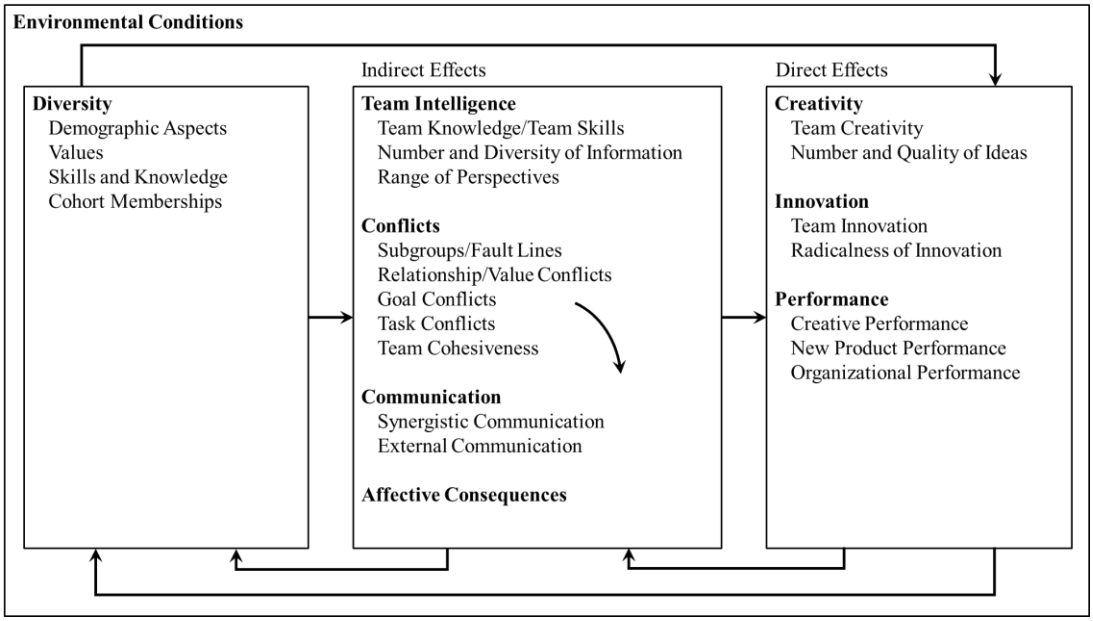

Figure 1: Effects of diversity (own representation, based on Milliken, Martins 1996 and Gebert et al. 2006)

Figure 1 shows the effects of team diversity on the aforementioned categories as reported in literature. The direct and indirect effects are differentiated.

Over the time a team works together, the influence of diversity can change. For example, the mental models of team members assimilate, thus lessening the effects of diversity on team outcome (Perry-Smith, Shalley 2003). Desired and undesired effects can be less frequent and intent, synergistic communication can improve, thus increasing team cooperation. However, the creative potential of diversity can also decrease in the process.

Most existing empirical studies on team diversity and its effects on innovativeness are cross-sectional studies that only examine a single diversity attribute and take a look at a particular point in team cooperation. Therefore they are not able to capture all of the contradictory effects, dynamic change, and nonlinear behavior (Kreidler, Tilebein 2013). In the following section we examine how simulation approaches, specifically System Dynamics and agent-based modeling, can help investigate the complex and changing correlation between diversity and creativity, innovativeness, and performance of teams.

Simulation of Diversity Effects

Simulation can be useful for problems that cannot be entirely explained empirically, that have dynamic nonlinear behavior and feedback, and whose effects address a basic tension or conflict (Davis et al. 2007; Stolarski, Tilebein 2009; Kreidler, Tilebein 2013 and Happach, Tilebein 2015). Simulation is ideal for applications where a theoretical background exists, but freedoms exist to allow new theories to be tested and developed (Davis et al. 2007).

In a previous publication (Stolarski, Tilebein 2009 and Kreidler, Tilebein 2013) we have shown that simulation models can be used to gain insight into the effects of diversity in teams. Davis et al. 2007 supply a roadmap on how to use simulation as methodological support in management research. In the following we take a closer look at step three of the Roadmap *"Choose a simulation approach"*. We compare the two simulation methods System Dynamics and agent-based modeling with respect to the diversity/innovation relationship.[1]

[1] Discrete-event simulation is not considered here. The discrete-event system itself is unchangeable and reacts only as a result of external influences (Tilebein, Stolarski 2009). This makes it inappropriate for modeling the contradictions and dynamic effects of team diversity.

System Dynamics shows a strong link to systems theory and cybernetics. The basic approach of System Dynamics is to model the causal relationships/links and structures of a problem. The dynamic change and feedback within the studied problem can be described with differential equations. (Sterman 2000; Schieritz, Milling 2003; Harrison, Klein 2007; Simon et al. 2008; Stolarski, Tilebein 2009 and Happach, Tilebein 2015)

Agent-based Modeling is based on artificial intelligence. Individual agents are modeled. Aggregated effects and emerging phenomena at higher levels are not modeled but rather arise from interactions between agents. The agents are equipped with rules for individual behavior and if applicable learning rules. On the basis of these rules they are able to interact and communicate with other agents. (Schieritz, Milling 2003; Simon et al. 2008; Stolarski, Tilebein 2009 and Happach, Tilebein 2015)

Comparison of System Dynamics and Agent-based Modeling in the Context of Team Diversity Effects

The three main effects of diversity in teams, contradictory results, dynamic behavior, and nonlinear effects, described in the previous chapters can be depicted using System Dynamics or agent-based modeling. Table 1 compares the simulation approaches based on the three effects.

Table 1: Comparison of System Dynamics and agent-based modeling based on the three basic effects of diversity

	Representation with System Dynamics	*Representation with Agent-Based Modeling*
Contradictory Results	Through change of dominant behavior as a result of the influence of different variables.	Through different influences of cooperation between agents.
Dynamic Behavior	Through feedback loops.	Through interaction and changes of individual agents and in the relationships between agents.
Nonlinear Effects	Through the interplay between variables (change of dominant behavior).	Through behavior rules regarding the interaction with other agents.

In the following section we further investigate if and how System Dynamics and agent-based modeling can represent diversity and its effects in teams. The strength and weaknesses in regard to the diversity/innovation relationship of both methods are highlighted.

While with System Dynamics the basic underlying structure of a research question can be modeled, agent-based modeling is better suited for considering team members on a micro-level.

When considering the effects of diversity in new product development teams, System Dynamics allows the underlying phenomenon, on team level to be modeled and simulated (Schieritz, Milling 2003; Stolarski, Tilebein 2009 and Happach, Tilebein 2015). The two predominant opposite effects – diversity as a resource and as a risk – with the described feedback effect of team members assimilating over time can be modeled on team level.

In a previous publication (Kreidler, Tilebein 2013), we have presented a highly simplified System Dynamics model of diversity and innovativeness in a new product development team. Here the contradictory effects – diversity as a resource and as a risk for team innovativeness – are shown on team level. The model also considers the dynamic change of the positive and negative effects, reflecting results of empirical studies. Those studies mostly view diversity effects on an aggregated team level and do not break the data down to individual team members' behavior. Individual experience or conflicts between single team members play a minor role compared to overlying team structures (Kreidler, Tilebein 2013).

Yet, for understanding the effects of team members' network positions, or to determine where fault lines most likely occur, the diversity attributes and behavior of individual team members must be investigated. For this, System Dynamics is less suited. Agent-based modeling offers the opportunity to depict single team members, their individual behavior, and their interaction with each other. In turn, team effects can only be depicted as a function of the behavior of single agents. For example, the innovation capability of a team can only be depicted as the innovation capability of individual members, no conclusions can be drawn about the whole team.

Tilebein, Stolarski 2009 show an agent-based simulation model of diversity and what effect diversity has on the decision process of a top management team. In this model members of the team are represented as agents. Based on their individual experiences and beliefs, they have different perceptions and interpretations regarding their preferred strategies. Team members

try to convince others of their choice for a strategy, until the team as whole has agreed. Individual settings, preferences, as well as information processing play an important role for influencing others team members (Tilebein, Stolarski 2009).

The two examples show that System Dynamics as well as agent-based modeling are suited to model and simulate the effects of diversity in teams. However, the methods focus on different topics. With System Dynamics, problems can be depicted on an aggregated macro-level, while using agent-based modeling individual behavior on the micro-level can be simulated.

Table 2 shows where the focus of each modeling approach lies when considering the effects of diversity in teams.

Table 2: Focuses of the simulation methods regarding team diversity effects

	System Dynamics	*Agent-based Modeling*
Diversity	Dispersion or variation of diversity within a team. No individual differentiation possible.	Individual attributes, like knowledge, abilities, identity, and demographics.
Team Intelligence	Knowledge/information available for the whole team, number and diversity of information, range of different perspectives.	Knowledge/information of single team members.
Conflicts	Conflicts in teams. Social integration.	Subgroup formation, fault lines, conflicts between individual team members.
Communication	Communication on team level.	Communication between individual team members.
Emotions	Team attributes like trust, motivation and contentment of the whole team.	Individual attributes such as contentment, motivation.
Creativity	Team creativity, the number and quality of ideas.	Individual creativity, the number of and quality of ideas.

Innovation	Innovativeness on team level and degree of radicalness of innovation.	Innovativeness of individual agents.
Performance	Creative performance on team level, new product performance.	Creative performance of individual team members, new product performance.
Environment	For example, team size or influence of communication environment as a team variables.	For example team size as number of individual agents, influence of communication environments as a change in the interaction rules between agents

Summary and Conclusion

In this paper we took a closer look at simulation as a complementary method to empirical studies for examining and understanding the complex effects of diversity in teams. First, we listed and categorized the effects of diversity in teams as reported in literature. We then examined the applicability of simulation as an additional method to empirical studies in the field of diversity research in teams. The two simulation approaches System Dynamics and agent-based modeling were introduced and considered as appropriate methods for simulating the effects of team diversity.

We concluded that both methods have their advantages and disadvantages for modeling the contradicting, dynamic, and nonlinear effects of diversity in teams. System Dynamics and agent-based modeling have a different view and focus on diversity in teams. With the help of System Dynamics it is possible to examine overlying aspects on a macro-level, while agent-based modeling focuses more on individual team members and their behavior on the micro-level.

Depending on the research goal, scholars have to decide which method is better suited for their specific problem context. For instance, in order to understand the formation of fault lines and subgroups, an agent-based simulation approach might be the appropriate choice. Agent-based simulation can also be better suited for depicting the network positions of team

members. For insight into correlations on team level, for example how diversity affects communication and innovativeness, a system dynamics model may more appropriate.

Table 3: Summary and Application Examples

	System Dynamics	*Agent-based Modeling*
Level	Problem structures, dynamic effects, feedback, and nonlinearity can be modeled. Statements about the behavior of single team members are not possible, only the overall structure can be modeled.	Individual agents and interactions between agents. Conclusions about the team can only be made as a function of single agents. Aggregated data and emerging effects cannot be modeled directly. It is difficult to depict measurable effects on a valid basis using agent-based modeling.
Empirical Data	Numerous empirical studies examine the behavior on team level and show the basic correlations between diversity and creativity, innovativeness and performance. Thus, empirical data exists as a basis for creating a model.	Effects on the behavior of single persons are barely examined in (cognitive) empirical studies. Additional studies that examine the behavior of individual team members are necessary. Further factors that might have an influence on the diversity/innovation relationship must be considered: for example it must be examined if individual team members' moods or opinions influence team work.

Application examples	Examination of the basis structures and behaviors of diversity, communication, and conflicts on creativity, innovativeness, or performance. Example: The effect of communication structures on team level on cooperation.	Examination of the behavior of individual team members and communication/conflicts between team members. Example: Examination of fault lines and subgroup formation. Depiction of (dynamic) network positions of individual team members.

Table 3 summarizes the focus of both methods, System Dynamics and agent-based modeling, for diversity effects in teams. The modeling level of each method for the diversity/innovation relationship is given, as well as the available data from empirical studies. Examples are listed for which aspect of team diversity the modeling approach can be more applicable.

This paper offers a guideline for using simulation as a complementary research method for investigating the effects of diversity in teams. We give researchers some insight to help decide, which of the two simulation methods – System Dynamics or agent-based modeling – might be better suited for analyzing a specific research question within the field of diversity effects in teams.

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