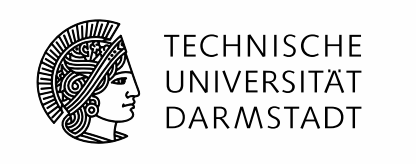
THE INFLUENCE OF SOCIAL INTERACTIONS ON INNOVATIVE ENDEAVORS IN ONLINE COMMUNITIES



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Zusammenfassung

Online Communities bieten ein großes Potenzial zum Finden zukünftiger Innovationen. Während Organisationen nach Inspirationen und Innovationen außerhalb ihrer Grenzen suchen, um wettbewerbsfähig zu bleiben, innovieren Individuen, um ihre eigenen Bedürfnisse zu erfüllen, und geben diese Innovationen anschließend frei. Online Communities stellen einen virtuellen Raum dar, in dem Individuen Ideen austauschen, sozial interagieren, zusammenarbeiten und auf anderen Ideen aufbauen können. Diese Dissertation untersucht, wie diese sozialen Interaktionen die Ideengenerierung und kontinuierliche Ideenentwicklung in Online Communities beeinflussen. Die drei Studien dieser Dissertation verwenden zwei einzigartige, große Datensätze, die die Untersuchung sozialer Interaktionen und ihrer Inhalte ermöglichen. Dabei bilden Topic Modeling und soziale Netzwerkanalyse die methodische Grundlage, um latente Inhaltsrepräsentationen der ausgetauschten Informationen zu messen. Hinsichtlich der Entstehung neuer Ideen enthält diese Dissertation zwei empirische Studien, die sich auf die Inhalte konzentrieren, auf die Individuen über ihre sozialen Kontakte zugreifen. Die erste Studie zeigt, dass die Kombination von redundanten und nicht-redundanten Informationen die Ideenneuheit begünstigt. Insbesondere Broker, die auf verschiedene soziale Informationen zugreifen, profitieren von redundanten (im Gegensatz zu nicht-redundanten) Inhalten, um neue Ideen zu generieren. Die zweite Studie betrachtet zeitabhängige soziale Interaktionen und gelangt zu dem Ergebnis, dass eine zeitliche Trennung zwischen Inspiration und Fokus auf spezifische Inhalte zu innovativeren Ergebnissen führt. Die dritte Studie konzentriert sich auf den fortlaufenden kollaborativen Ideenentwicklungsprozess in Online Communities und untersucht, wie soziale Einflüsse die Ideenentwicklung beeinflussen, nachdem sie geteilt wurden. Nach den Befunden der dritten Studie hilft die Social Impact Theorie zu erklären, wie soziale Einflüsse die Ideenentwicklungsrichtung in Online Communities beeinflussen. Durch die verschiedenen Perspektiven auf innovative Vorhaben in Online Communities trägt diese Dissertation zur Literatur über Online Communities, soziale Netzwerke und User Innovationen bei. Insbesondere wird die Bedeutung sozialer Interaktionen für Innovationen hervorgehoben und die Abhängigkeit dieser Beziehungen vom Inhalt, dem Zeitpunkt und dem sozialen Einfluss der sozialen Interaktionen.

Schlüsselwörter: Soziale Interaktionen, Innovation, Sozialer Einfluss, Online Communities, Ideenentwicklung, Ideenentstehung, Soziale Netzwerkanalyse, Netzwerkinhalt

Abstract

Online communities offer great potential for sourcing future innovations. While organizations search for inspiration and innovations outside their organizational boundaries to stay competitive, individuals innovate to solve their own needs and subsequently freely reveal these innovations. Online communities constitute a virtual space for individuals to share ideas, socially interact, collaborate, and build on others' ideas. In this dissertation, I investigate how these social interactions influence the generation of ideas and the ongoing idea development in online communities. The three studies of this dissertation use two unique large datasets that allowed the investigation of social interactions and their contents. In doing so, topic modeling and social network analysis techniques build the methodical foundation to measure latent content representations of the information that is exchanged in online communities. Regarding the generation of new ideas, this dissertation includes two empirical studies that focus on the content that individuals access through their social peers. The first study reveals that the combination of redundant and non-redundant information favors idea newness. In particular, brokers accessing diverse social information benefit from redundant content for generating new ideas. In contrast, non-redundant contents have detrimental effects on brokers' social non-redundancy regarding brokers' idea newness. The second study takes a time-dependent view on social interactions and finds that a temporal separation between inspiration and focus on specific contents leads to more innovative outcomes of individuals engaging and innovating in online communities. By focusing on the ongoing collaborative idea development process in online communities, the third study investigates how social influences shape the trajectory ideas take after they got initially shared. The findings of the third study show that social impact theory helps explain how social influences affect the development directions of ideas in online communities. By taking different perspectives on innovative endeavors in online communities, this dissertation contributes to the literature on online communities, social networks, and user innovation. Specifically, this dissertation emphasizes the importance of social interactions for innovations and this relationships' dependence on the actual content, timing, and social impact of social interactions.

Keywords: Social interactions, innovation, social influence, online communities, idea development, idea generation, social network analysis, network content

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Chapter 1

Introduction

1.1 Motivation

There is a plethora of inspiration and innovations outside organizational boundaries. Innovation is not happening solely behind closed doors. Since knowledge about customer needs is unevenly distributed and sticky, innovative activities take place outside traditional R&D units (Dahlander & Gann, 2010; E. von Hippel, 1994, 2017). Further, organizations do not exclusively possess the means to innovate. Instead, digitization and communication over the internet enable individuals, other firms, or open collaborative innovation efforts to compete with traditional organizations (Baldwin & von Hippel, 2011). As a result, future innovations will originate from outside organizations and are, thus, not under their direct control. At the same time, increasing uncertainty and complexity burden internal innovation processes. In fact, external contributors can find high-quality solutions to complex challenges faster and cheaper than internal R&D units (Lifshitz-Assaf, 2017). Thus, to stay innovative and competitive, organizations should search for and integrate external ideas (e.g., Afuah & Tucci, 2012; Bogers et al., 2017; Fisher, 2019).

Multiple options exist to extend innovation activities and capabilities sourcing innovations beyond organizational boundaries (Bogers et al., 2017). Among these options, online communities constitute an organizational form that allows external individuals to interact with each other, share knowledge, and contribute to solve problems (Faraj, von Krogh, Monteiro, & Lakhani, 2016). Individuals around the world spend their free time developing ideas across a diverse set of domains to solve their unmet needs (E. von Hippel, 1986, 2017). In the United Kingdom alone, private individuals spend 1.4 times more money on their innovations than consumer good firms' R&D expenditures (E. von Hippel, de Jong, & Flowers, 2012). After creating innovations, individuals often freely reveal them and do so out of joy (E. von Hippel & von Krogh, 2006). Further, the rise of the internet and web 2.0 enabled individuals to share their thoughts and ideas in interactive online communities (Faraj, Jarvenpaa, & Majchrzak, 2011). Such communities open the possibility for individuals to connect with like-minded

people who also increase organizations' reach searching for potential innovations. Prominent anecdotal examples emphasize the practical relevance across diverse domains. For instance, NASA opened its innovation process by posting scientific challenges online and received high-quality submissions from individuals at an astonishing speed (Lifshitz-Assaf, 2017). British Petroleum received over 120,000 suggestions to help solve the Deepwater Horizon accident in 2010 (Piezunka & Dahlander, 2015). Other examples that integrate private individuals in their innovation process via online communities and contests include Netflix, Dell, Starbucks, InnoCentive, TopCoder, and Threadless (Acar, 2019; Baldwin & von Hippel, 2011; Bauer, Franke, & Tuertscher, 2016; Bayus, 2013; Boudreau, Lacetera, & Lakhani, 2011; Dong & Wu, 2015). Further, the success of the operating system Linux highlights the promises of open-source software (Lakhani & von Hippel, 2003; von Krogh & von Hippel, 2006). Individuals around the world contribute software code in their free time and collectively outperform traditional software development firms. Entire multi-billion-dollar businesses are built around online communities and this open model. For instance, IBM acquired the open-source software company Red Hat for 34 billion US dollars in 2019 (Red Hat, 2019), and Microsoft acquired GitHub, a leading online platform for hosting and collaborating on software projects, for 7.5 billion US dollars in 2018 (Microsoft, 2018). Furthermore, governments also use online communities to access the innovative power of voluntary individuals on the internet. For instance, during the Covid-19 pandemic in 2020, many governments organized online hackathons to look for problems and solutions alike (WirVsVirus, 2020). In sum, online communities have highly valuable and innovative potential outside organizational boundaries (Dahlander & Frederiksen, 2012; Poetz & Schreier, 2012).

Online communities constitute an important stakeholder group and promise advantages for organizations (Bogers et al., 2017; Fisher, 2019). In addition to the innovative potential, online communities can be used for testing products or establishing platforms and network effects. For instance, TensorFlow—Google's open-sourced machine learning framework—gained much momentum in the community by enabling users to create custom machine learning models easily and integrates well with other (paid) services such as cloud computing. However, these stakeholders are fluid in nature and active beyond organizational control (Faraj et al., 2011). Thus, there is uncertainty for organizations about the directions and outcomes of innovative endeavors in online communities. Engaging with the community and monitoring information

flows can yield information benefits that reduce this uncertainty and provide access to innovations (Fisher, 2019).

Understanding the inner mechanisms of online communities is essential to capture their innovative potential. Since online communities depend on voluntary contributors, individuals' behavior particularly shapes the outcomes and value of a community. Individuals are intrinsically motivated to innovate and contribute their knowledge (Lakhani & Wolf, 2003). They interact with each other, collaborate, and build on others' ideas (Baldwin & von Hippel, 2011; Faraj et al., 2011; Stanko, 2016). As a result, online communities form social entities. This open organizational form is self-organizing and social dynamics, governance, and norms emerge within online communities (Bauer et al., 2016; Klapper & Reitzig, 2018; O'Mahony & Ferraro, 2007). Social relationships and hierarchies let community members act strategically when interacting with social peers (Klapper, Piezunka, & Dahlander, 2021). The recognition of peers also motivates individuals to contribute (Chen, Wei, & Zhu, 2018). Consequently, the contribution behavior in online communities is a highly social process. Uncovering if and how these social dynamics affect the emergence and development of innovations in online communities has the potential to offer insights for organizations to find, support, and steer innovative endeavors.

In conclusion, online communities have huge innovative potential but underlay complex social mechanisms. Organizations cannot innovate behind closed doors, while volunteers that innovate and solve problems faster and cheaper than internal development efforts exist outside organizational boundaries (Lifshitz-Assaf, 2017). Instead, organizations need to socially engage with online communities to gain benefits (Fisher, 2019). Thus, this dissertation investigates how social interactions influence innovative endeavors in online communities.

1.2 Research Gap and Research Questions

Online communities are highly social (Faraj et al., 2016), provide sources for innovations (Dahlander & Frederiksen, 2012), and offer advantages for organizations (Fisher, 2019). However, the inner mechanisms that lead to knowledge creation and innovations within online communities are not well understood (Faraj et al., 2016; Sundararajan, Provost, Oestreicher-Singer, & Aral, 2013). Since online communities can be independent, self-maintaining, and not directly controlled by an organization, research and knowledge about the inner mechanisms

could help to understand how innovations emerge and how organizations can (actively or passively) engage with online communities. Given the social nature of online communities, this dissertation is based on two research streams: online communities as part of open innovation and social networks.

Prior research on online communities focused on individuals' contribution behavior (Chen et al., 2018; Faraj & Johnson, 2011; Kokkodis, Lappas, & Ransbotham, 2020), motivations for participation (Hausberg & Spaeth, 2020; Lakhani & Wolf, 2003; von Krogh, Haefliger, Spaeth, & Wallin, 2012), innovative outcomes (Bayus, 2013; Dahlander & Frederiksen, 2012; Poetz & Schreier, 2012), and governance of communities (Bauer et al., 2016; He, Puranam, Shrestha, & von Krogh, 2020; O'Mahony & Ferraro, 2007). Adjacent research streams on crowdsourcing and idea contests investigated how organizations interact with external contributors and online communities (e.g., Afuah & Tucci, 2012; Boudreau et al., 2011). The process of idea selection and feedback shows the bounded rationality of individuals and the existence of social influences on behavior (Piezunka & Dahlander, 2015, 2019). Further, individuals share ideas, interact, and collaborate in online communities (Baldwin & von Hippel, 2011). Individuals are embedded in social networks (Safadi, Johnson, & Faraj, 2021) and social norms, as well as hierarchies, emerge (Bauer et al., 2016; Johnson, Safadi, & Faraj, 2015; Klapper & Reitzig, 2018). Network positions yield expertise and reputation and predict innovative outcomes (Dahlander & Frederiksen, 2012). While prior research underlines the social dynamics within online communities which can affect innovative endeavors, the inner workings of how these social dynamics unfold are still unclear (Faraj et al., 2016).

At the same time, apart from online communities, there are different arguments in the literature on social networks about social networks' effects on innovations (Perry-Smith & Mannucci, 2017). Many studies argue and empirically investigate how social structures and interactions affect innovative outcomes (e.g., Burt, 2004; Perry-Smith, 2006). The fundamental argument is that individuals access information and knowledge from their direct peers and their position in a broader network. This information can lead to inspiration and recombination of knowledge elements or facilitate the transfer of tacit knowledge (Burt, 2004; Granovetter, 1977; Perry-Smith, 2006; Perry-Smith & Mannucci, 2017; Sosa, 2011). Although social networks' relationship with innovative endeavors has been studied extensively, there are ongoing conversations and open questions. First, Perry-Smith and Mannucci (2017) describe the current controversy about the favorability of redundant and non-redundant information. Second,

researchers started to question the inherent relationship between network structure and network content (Burt, 2010; Rodan & Galunic, 2004). Third, network studies and measures often miss detailed information about inner workings, such as the dependence on time (Faraj et al., 2016; Sundararajan et al., 2013).

In combination, these two research streams open promising avenues to investigate innovative endeavors in online communities. To condense the outlined previous research, innovations, as well as social dynamics, emerge in online communities, and social interactions affect innovations. Although online communities have a fluid nature (Faraj et al., 2011, 2016), social interactions and idea developments can take place and change over more extended time periods. However, how these social dynamics unfold and influence innovative endeavors remains unclear. Consequently, I pose three specific research questions for this dissertation that aim at different open research gaps and perspectives along the way of innovative endeavors in online communities.

First, I focus on innovative outcomes driven by the interplay of different information in social networks. Traditionally, researchers argue that social networks provide access to information and assume an inherent relationship between network structure and content (Aral & Van Alstyne, 2011; Burt, 2010). For instance, individuals positioned in the center of information flow through weak ties or connecting different subgroups gain information advantages and can thus benefit from information arbitrage but also from combining diverse information (Burt, 2004; Granovetter, 1977). In contrast, strong ties to close peers enable the transfer of more complex and tacit knowledge that might be necessary for generating innovations (Sosa, 2011). Both arguments provide valuable explanations for the function of social networks in innovative endeavors. However, recent studies question the inherent relationship between network structure and content and found independent and complementary effects (Piezunka & Dahlander, 2015; Rodan & Galunic, 2004; Wang, Rodan, Fruin, & Xu, 2014). Two individuals positioned in the same structural network position can access information that varies in diversity. As a result, the potential advantages of a specific network position may depend on the actual information that is accessible. This contingency could impact how individuals generate new ideas within online communities. Thus, I pose the following first research question.

Research question 1: *How do social and content information in social networks affect innovative endeavors in online communities?*

Second, the history of interactions in social networks could help explain how information exchange shapes ideas over time. In addition to being content-agnostic, network studies are also often time-agnostic (Sundararajan et al., 2013). Static observations of social networks condense past interactions to a single point in time and thus do not represent dynamics over time and potential changes of activities and interests. Depending on their strength, ties can hold over a long time period and can be reactivated when needed (Dahlander & McFarland, 2013). Thus, once encountered, still accessible information and contacts might be represented in static social networks. However, active ties can change and are not constant. Over time, the required knowledge to be creative changes (Mannucci & Yong, 2018), and different phases along an idea journey need to activate different network structures (Perry-Smith & Mannucci, 2017). Individuals can have connections to a variety of diverse information at a particular point in time while focusing on specific topics in another time frame. Aggregating all interactions over time in a static network will hardly capture this situation. Even if the static network still holds information about weak and strong interests, time-dependent information about the variety of interests is lost. These dynamics could, however, shape innovative endeavors over time. Online communities represent a special context for exchanging information because this exchange is stored in textual posts. Instead of taking place on a single point in time with a set number of peers, additional individuals can pick up and show interest in prior or ongoing conversations. The fluid nature of online communities further underlines the importance of social dynamics' time dependence and the resulting changing interactions as well as interests of community members (Faraj et al., 2011). Archived communication data and interaction data open a unique possibility to investigate individuals' changing interaction behavior and allocation of interests. Consequently, time-dependent interest allocation represents the core of this dissertation's second research question.

Research question 2: *How does the time-dependent interest allocation (between inspiration and focus) of online community members influence their idea's innovativeness?*

Third, the ongoing development after generating and sharing ideas in online communities might be influenced by social forces. Once an idea is shared, other community members can interact and contribute to the idea by providing feedback or suggestions for improvements. As a result, original ideators are exposed to different influences that could affect their decisions on the ideas' future development trajectories. Prior research already found that social forces influence the behavior of individuals in online communities by investigating social dynamics such as social structures (Bauer et al., 2016; Klapper et al., 2021; O'Mahony & Ferraro, 2007), motivations to contribute (Chen et al., 2018; Hausberg & Spaeth, 2020; Lakhani & Wolf, 2003; von Krogh et al., 2012), or the influence of peers (Chen et al., 2018; Dewan, Ho, & Ramaprasad, 2017; Roethke, Klumpe, Adam, & Benlian, 2020; Schneider, Klumpe, Adam, & Benlian, 2020). Governance structures and hierarchies emerge in which individuals also act strategically (Klapper et al., 2021; O'Mahony & Ferraro, 2007; Shah, 2006). Although online communities are virtual spaces and many individuals contribute voluntarily, governance disputes take place (He et al., 2020). Self-maintaining communities develop behavioral norms and cohesion against outsiders (Bauer et al., 2016). Newcomers must follow behavioral rules to become part of a community (von Krogh, Spaeth, & Lakhani, 2003). Community members are intrinsically motivated to contribute, interact with others, and value peer recognition (Lakhani & Wolf, 2003; von Krogh et al., 2012). Communications' linguistic style also affects recurring contributions (Piezunka & Dahlander, 2019), and the social presence of missing anonymity influences individuals' contribution behavior (Pu, Chen, Qiu, & Cheng, 2020). Further, the overall community and especially close peers influence and socially nudge community members' behavior (Dewan et al., 2017; Wang, Zhang, & Hann, 2018). In sum, social influence in online communities is prevalent. However, despite the relevance of understanding innovation trajectories in online communities, how social forces shape the direction of collaborative development remains unanswered. Such mechanisms could affect the success or failure of these innovations. As a result, this importance and the gap in the literature yield the third research question of this dissertation.

> ***Research question 3:*** *How do latent social influences affect the direction of idea development in online communities?*

1.3 Conceptual Background: Online Communities and Social Networks

1.3.1 Online communities

Despite the interest in previous research, there is no clear definition of communities or online communities (Faraj et al., 2016). However, online communities' key attributes are social interactions, information exchange, and internet-based communication (Dahlander & Frederiksen, 2012; Faraj et al., 2016; Fisher, 2019; Safadi et al., 2021). Thus, in this dissertation, online communities constitute a virtual space on the internet that enables individuals to share thoughts and exchange information. This information exchange can take place, for instance, in the form of textual posts. These posts, unless actively deleted, are stored and displayed over long time periods so that community members can observe previous activities of other members. Further, community members can communicate directly with peers through expressing likes or commenting behavior to give feedback or start a discussion. Often these posts are visible to others so that the communication is not limited to the initial participants and a specific point in time. An important characteristic of online communities is their fluid nature. Community memberships, contributions, and the knowledge exchanged are fluid and not stable over time (Faraj et al., 2011, 2016).

Online communities exist for nearly every topic and take different forms depending on the purpose and owner. For instance, online communities' thematic domains include, for instance, music (Dewan et al., 2017), extreme sports (Franke, von Hippel, & Schreier, 2006; Hienerth, von Hippel, & Berg Jensen, 2014; E. von Hippel & Kaulartz, 2021), diabetes (Kokkodis et al., 2020), parenting (C. D. von Hippel & Cann, 2021), and software (von Krogh & von Hippel, 2006). The information exchange between community members leads to the emergence of innovations (Dahlander & Frederiksen, 2012), creates value (Franke et al., 2006; Poetz & Schreier, 2012), and provides entrepreneurial opportunities (Autio, Dahlander, & Frederiksen, 2013). Online communities can be hosted by an organization to provide customer support (Hwang, Singh, & Argote, 2019) or receive ideas (Bayus, 2013). Instead of establishing self-hosted communities or in order to access distant communities and knowledge, intermediaries such as InnoCentive serve as brokers between organizations and private individuals (Acar, 2019; Jeppesen & Lakhani, 2010). Online communities can also be independent and self-maintaining and develop their own governance structures (Bauer et al., 2016; O'Mahony & Ferraro, 2007). This dissertation's focus lies on online communities characterized by open

interactions to share ideas and knowledge in order to analyze the social dynamics according to the research questions.

In addition to innovative outcomes in online communities, prior research primarily focused on the motivation of volunteers to participate and on their contribution behavior. Online communities act as a space for knowledge flow and create value by facilitating the creation of new knowledge, innovations, and solving problems (e.g., Dahlander & Frederiksen, 2012; Faraj et al., 2016; Fisher, 2019; Franke & Shah, 2003; Jeppesen & Lakhani, 2010; Jeppesen & Laursen, 2009). Individuals often freely reveal their knowledge and innovations without restricting their use by others (E. von Hippel & von Krogh, 2006). Due to online communities' fluid nature, continuous contributions by community members are essential for maintaining this knowledge flow. Thus, the motivations of individuals for voluntary contributions are important and extensively investigated. Community members engage in online communities often out of joy and based on intrinsic motivation (Hausberg & Spaeth, 2020; Lakhani & Wolf, 2003). Further, individuals' motivation to participate in and contribute to online communities also includes extrinsic motivation, social identity aspects, reputation, peer-recognition, organizations' attributes, gratifications, community commitment, and learning new skills (Bagozzi & Dholakia, 2006; Bateman, Gray, & Butler, 2011; Hausberg & Spaeth, 2020; Jeppesen & Frederiksen, 2006; Lakhani & Wolf, 2003; Ma & Agarwal, 2007; Spaeth, von Krogh, & He, 2015; H.-T. Tsai & Bagozzi, 2014; Wasko & Faraj, 2005). However, contributions are not constant. Bayus (2013) found that past success in ideation communities affect the novelty of individuals' subsequent ideas so that the ideas stay similar to the successful one. As new input is crucial for online communities, scholars investigated how contributions can be fostered apart from pecuniary awards by turning passive community members into active contributors (Kokkodis et al., 2020), providing feedback as an explanation for idea rejections (Piezunka & Dahlander, 2019), or designing information technology artifacts for gamification (Chen et al., 2018). In sum, individuals' motivation and contribution behavior is highly social and depends to a great extent on social dynamics within online communities.

Online communities constitute social systems with social interactions, social structures, social norms, and social capital (Bauer et al., 2016; Dahlander & Frederiksen, 2012; Faraj et al., 2016; Levina & Arriaga, 2014; Thies, Wessel, & Benlian, 2016; von Krogh et al., 2012; Wasko & Faraj, 2005). Voluntary contributions build the foundation of information exchange and knowledge flow. Shared ideas and content generated in collaboration hold benefits for other

active or passive participants who can recombine, reuse, and remix existing knowledge and ideas (Haefliger, von Krogh, & Spaeth, 2008; Stanko, 2016). To organize these value-creating activities, new governance forms and hierarchies emerge in which community members act strategically (Klapper et al., 2021; O'Mahony & Ferraro, 2007; Shah, 2006). Community members also develop social norms and protect others' intellectual property (Bauer et al., 2016). Furthermore, the community and direct social peers influence individuals' behavior in online communities (Bapna & Umyarov, 2015; Dewan et al., 2017; Wang et al., 2018). Lastly, interactions within social networks affect contribution and innovative outcomes in online communities (e.g., Dahlander & Frederiksen, 2012; Singh & Phelps, 2012).

1.3.2 A social network perspective on innovation

Innovative endeavors are a social process. Prior research extensively studied the relationship between social interactions and innovative outcomes (e.g., Perry-Smith, 2006, 2014; Perry-Smith & Shalley, 2003; Sosa, 2011; Woodman, Sawyer, & Griffin, 1993). Social interactions between multiple individuals build a social network. A social network can be formalized with individual actors as nodes that are connected via edges. Edges can be expressed by weights that represent the strength of the connection between two nodes. This formalized representation of social networks allows measuring certain network features of the overall network and individual network actors such as centrality (e.g., Borgatti, 1995; Burt, 1992; Perry-Smith, 2006). The fundamental assumption in the network literature is that social networks provide information that flows between nodes (e.g., Aral & Van Alstyne, 2011). Conceptual and empirical studies sought to understand how information flows in social networks benefit the generation of innovations. Very close contacts are assumed to have similar knowledge. Thus, strong ties that connect close contacts provide familiar knowledge. In contrast, direct peers who are dissimilar are likely to be loosely connected. As a result, weak ties offer diverse knowledge. Both seemingly contradictory situations (familiarity and diversity) facilitate innovative endeavors.

Diversity and non-redundant information increase inspiration and individuals' creativity (Granovetter, 1977; Perry-Smith & Mannucci, 2017; Taylor & Greve, 2006). Network structure and direct ties can provide such diverse knowledge. Weak ties to different and diverse peers stimulate associations, provide diverse feedback, and facilitate knowledge recombination (e.g., Burt, 1992; Granovetter, 1977; Schumpeter, 1934). Thus, weak ties benefit the generation of

new ideas. In contrast, similar arguments suggest that exceptionally strong connections could hinder creativity by promoting conformity (Fleming, Mingo, & Chen, 2007; Uzzi & Spiro, 2005). In addition to direct ties, network positions can offer several advantages for innovative endeavors. In particular, a broker who is positioned in a structural hole and bridges otherwise different unconnected subgroups obtains information advantages that lead to good ideas (Burt, 2004; Phelps, Heidl, & Wadhwa, 2012). The position between subgroups yields diverse information about trends that others do not possess. Thus, brokers are associated with potential information arbitrages in social networks. Furthermore, in the field of user innovation, broker status relates to *lead userness*—being ahead of a trend and receiving high benefits from a solution and thus innovating to fulfill own needs (Kratzer, Lettl, Franke, & Gloor, 2016; E. von Hippel, 1986, 2017). However, some studies could not confirm a positive relationship between structural holes and innovative outcomes (Perry-Smith, 2006; Zhou, Shin, Brass, Choi, & Zhang, 2009).

Familiarity and redundant information provide trust and mutual support, which also facilitates creativity (Chua, Morris, & Mor, 2012; Sosa, 2011). Close connections enable the transfer of tacit knowledge and facilitate collaboration (E. W. Morrison, 2002; Reagans & McEvily, 2003). Further, expertise and deep knowledge in certain domains help to identify creative opportunities in these domains (Dane, 2010). Thus, the amount of tacit knowledge provided by close contacts might be necessary to generate innovations (Aral & Van Alstyne, 2011). In sum, network structure and direct ties familiarity and diversity both offer important advantages for innovative endeavors.

Recent studies take a more differentiated view to explain the advantages of network features that provide familiarity and diversity. Perry-Smith and Mannucci (2017) argue that ideas follow a journey with different phases—generation, elaboration, championing, and implementation—and that each phase has different requirements of social networks. While inspiration with many diverse contacts and, thus, weak ties are favorable for generation, the authors argue that for elaboration, strong ties provide the necessary tacit knowledge and emotional support. Further, network literature is often content-agnostic, and researchers started to question and investigate the inherent relationship between network structure and network content (Aral & Van Alstyne, 2011; Burt, 2010; Rodan & Galunic, 2004). Studies that combined network structure and content found that network structure and content are independent (Piezunka & Dahlander, 2015; Wang et al., 2014) and complement each other (Moreira, Markus, & Laursen, 2018; Rodan &

Galunic, 2004; Safadi et al., 2021; Schillebeeckx, Lin, & George, 2019; Ter Wal, Alexy, Block, & Sandner, 2016). In fact, there are several contingencies of network features. For instance, network features' effects rely on the information diversity that network actors encounter (Moreira et al., 2018), on team members' expertise (Schillebeeckx et al., 2019), connected actors' knowledge (Ter Wal et al., 2016), managers' access to heterogeneous knowledge (Rodan & Galunic, 2004), and the attention allocation to direct peers (Rhee & Leonardi, 2018). In addition, Rost (2011) found that weak network structures, such as structural holes, can be complemented by strong ties. In conclusion, information available in social networks yield many advantages for innovative endeavors, and seemingly contradictory arguments depend on the context and can complement each other.

Furthermore, methodical advances and access to archival data of online communications allow to measure network features objectively and to analyze content without the need to interfere. With the communication history of online communities, it is possible to construct complete social networks that capture information flows beyond direct ties (Perry-Smith, 2006). Time-stamped interactions further enable the investigation of dynamics over time. Text analysis and especially topic modeling has gained popularity in recent management research (Hannigan et al., 2019; Hwang et al., 2019; Kaplan & Vakili, 2015; Safadi et al., 2021; Taeuscher, Bouncken, & Pesch, 2021; Vakili & Kaplan, 2021). The use of topic modeling lets researchers analyze latent topic representations of texts that capture the texts' content. One particular unsupervised machine learning method is called Latent Dirichlet Allocation (LDA) (Blei, Ng, & Jordan, 2003). The method assumes that individuals write texts or documents with previously known topics. The author of a document expresses these latent topics with specific words in mind. The result of applying LDA on a corpus of documents is a document-topic distribution for each document and a topic-word distribution for each topic. The document-topic distributions can be used, for instance, for measuring novelty (Hannigan et al., 2019; Kaplan & Vakili, 2015), distinctiveness (Taeuscher et al., 2021), or connectedness of knowledge elements (Safadi et al., 2021).

In conclusion, individuals socially interact and collaboratively pursue innovative endeavors in online communities. Innovative endeavors are a social process and, as outlined above, prior research leaves important aspects unanswered. Thus, this dissertation aims to answer three research questions that focus on (1) social network structure and content, (2) time-dependence of interactions, and (3) social influences on idea developments in online communities.

1.4 Overview of Studies

To answer the three research questions, this dissertation contains three empirical studies, each with a deductive approach developing hypotheses that are tested by collecting and empirically analyzing real-world data. The following paragraphs will outline the content and results of each study. Paralleling the research questions, the three studies include social aspects along the way of innovative endeavors in online communities. In online communities, individuals interact with each other, and this, in turn, might influence the generation and development of ideas. Figure 1 illustrates the different angles of each study to understand a distinct part of this endeavor. The first study investigates the relationship between individuals' positions in social networks and their ideas' newness depending on the actual content they access from their peers. Thus, study A combines the social and content aspects of social networks by investigating the difference of network positions between individuals. Study B primarily focuses on time-dependent information about social interactions in online communities before ideas get revealed. In doing so, the study explores the favorable order of getting inspired by diversity or focusing on narrow content by taking an intra-personal perspective over time. While the first two research studies focus on individuals' social behavior in online communities and the subsequent generation and sharing of innovative ideas, study C investigates the social dynamics of the development trajectory that ideas take after revealing them. In addition, study C explores the community's collective behavior instead of individual behavior.

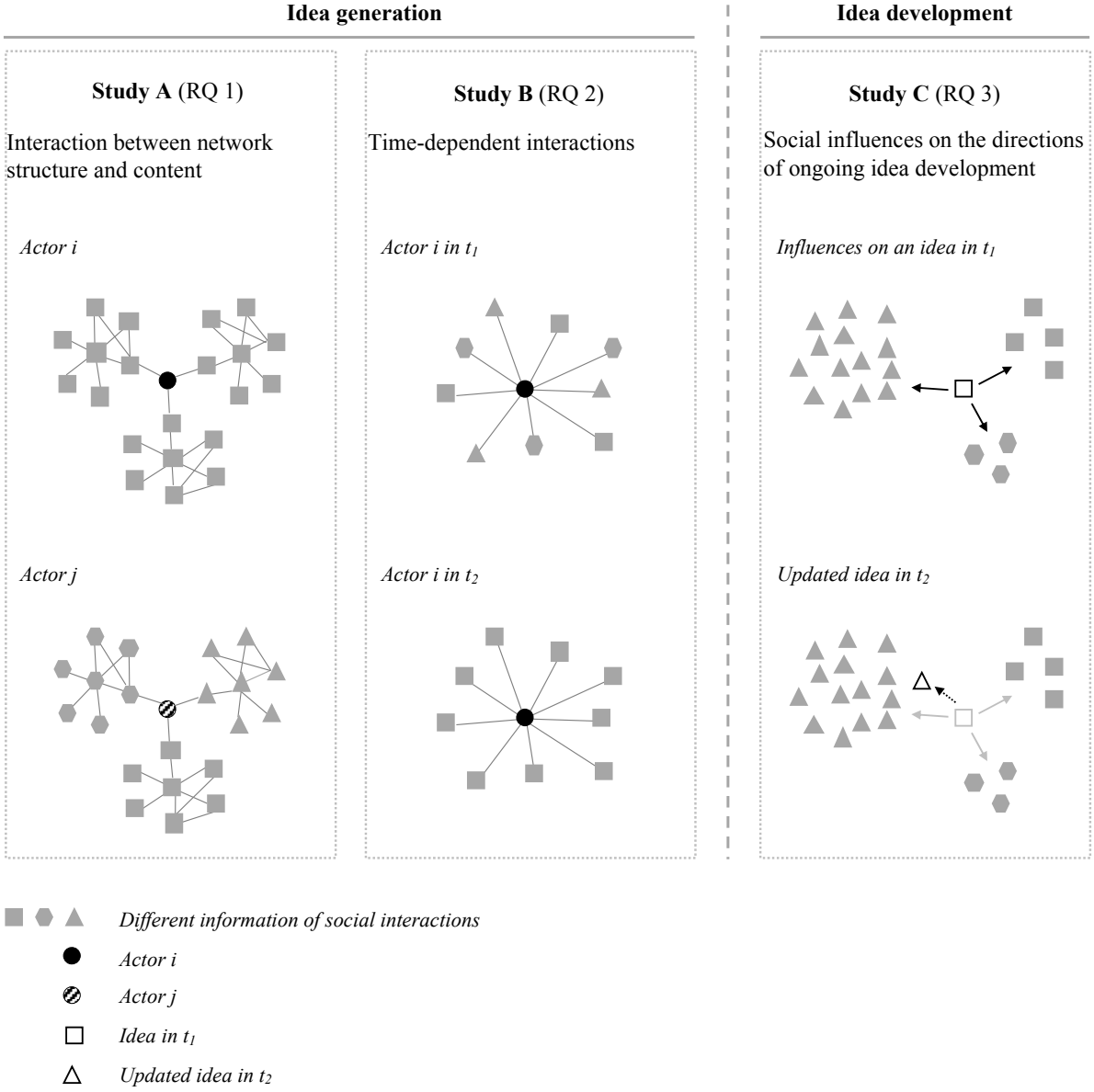

Figure 1. Conceptual overview of this dissertation's studies and research questions (RQ).

Table 1 shows an overview of the three research studies and each study's research question, methodical approach, and data set. While all studies theorize about as well as capture social interactions and measure the content of these interactions, the first two studies focus on the generation of innovative ideas, and study C concentrates on the subsequent development within the community. Consequently, the studies were conducted in different research contexts and with different datasets. Studies A and B take place in the context of an online maker community. In this community, individuals can share their ideas (e.g., hardware projects and prototypes) and comment on others' ideas. Idea descriptions and community members' timestamped

comments enable investigations of both the contents and time dependence of interactions in social networks. Thus, time-dependent social networks derived from community members' commenting behavior were used to explore the influence during the generation of ideas within online communities. Study C instead uses a dataset gathered from GitHub, an online community for hosting and collectively developing open-source software projects. Community members can exchange information by raising issues, contributing code, suggesting new features, and discussing these contributions through comments. Thus, the ongoing development of these open-source software projects might underly social dynamics and influences. Again, timestamped data enables the investigation of social interactions and their influences on innovation endeavors over time. Further, all three studies include conceptual arguments about the content of the social interactions between community members, which makes measuring this content essential. To achieve this, textual analysis (i.e., topic modeling) is applied to the textual posts of the two online communities to extract latent topics. Such content representations in combination with time-dependent social interactions open the possibility to answer this dissertations' research questions with a deductive and empirical approach. In the following, I summarize each study's findings before presenting the studies in total length in chapters 2, 3, and 4.

Table 1. Detailed overview of this dissertation's studies.

Study	Title	Ideation phase	Research question	Dataset	Method
A	The influence of information depth and information breadth on brokers' idea newness in online maker communities	Idea generation	*How do social and content information in social networks affect innovative endeavors in online communities?*	18,146 idea descriptions, 19,919 profiles, and 52,663 comments of hackaday.io	Social network analysis, topic modeling, hierarchical regression analysis
B	Inspiration before focus – time-dependent interest allocation and idea innovativeness in online communities	Idea generation	*How does the time-dependent interest allocation (between inspiration and focus) of online community members influence their idea's innovativeness?*	18,146 idea descriptions, 19,919 profiles, and 52,663 comments of hackaday.io	Social network analysis, topic modeling, hierarchical regression analysis
C	Social influence on idea development in online communities	Idea development	*How do latent social influences affect the direction of idea development in online communities?*	84 projects, 98,504 issues, 84,404 pull requests, and 568,504 comments of GitHub	Topic modeling, clustering, fixed-effects, hierarchical regression analysis

Study A follows the first research question and investigates individuals' social network positions and the contents that individuals access through their position. For a long time, social network studies have assumed an inherent relationship between the structure and content of a network. However, more recent studies found independent and complementary effects. These findings open the path for theorizing about more complex relationships and about contingencies that could combine seemingly contradictory arguments. For instance, both weak network features, as well as strong connections and closure, show valuable mechanisms that can facilitate the generation of innovations. Similarly, knowledge breadth and knowledge depth are both considered to benefit creative thinking. To solve this controversy, researchers introduced contingencies. For instance, Mannucci and Yong (2018) found that the effect of movie directors' knowledge breadth and depth on creativity depends on career age. The combination of different network features also complement each other (Rost, 2011).

Following the arguments of contingencies on social network features, we focus on brokers as a particular network position in this study. Brokers bridge different subgroups and can therefore benefit from better access to information that flows between those subgroups. Brokers can use this diverse information to create new ideas as knowledge recombination (e.g., Burt, 1992; Granovetter, 1977; Schumpeter, 1934). However, we argue that broker status' advantages depend on the number of knowledge elements they access. Given the independence of network structure and content, brokers can access either diverse or similar information from their peers. While brokers receive diverse social information, they need to be able to interpret this information to capture its value and create new ideas. The combination of diverse information of both network position and accessed content makes processing the information more complex and could lead to cognitive overload. In contrast, accessing similar information facilitates the interpretation of diverse social information. Thus, we argue that the newness of brokers' ideas is positively influenced when accessing similar information while accessing diverse information.

To test our hypotheses, we chose the maker movement as a suitable research context. We collected a unique dataset of 18,146 ideas, 19,919 profiles, and 52,663 comments by crawling the online community hackaday.io. Based on the timestamped comments of individuals on others' ideas, we constructed for each day in our observation period (1,671 days) a separate social network. For each network, we calculated each individual's broker status measured by the betweenness centrality, which captures the portion of shortest paths in the network that go

over a focal network actor (Borgatti, 1995; Kratzer et al., 2016; Perry-Smith, 2006). Further, the use of LDA lets us capture content representations of idea texts. These content representations provided information about the content diversity individuals accessed and about the newness of ideas. As a result, we were able to empirically study the complementary effects of network structure and content on idea newness. Our findings support our hypotheses and underline the importance of both social structures and content in networks.

Study B takes a different approach than study A to achieve a more fine-grained investigation of individuals' time-dependent social interactions. Following research question 2, social network literature is time-agnostic (Sundararajan et al., 2013). However, individuals show interest in different topics, and their interests might change over time. Thus, individuals can be very focused on particular information or get inspired by many different inputs at different points in time. In fact, Perry-Smith and Mannucci (2017) argue that innovative endeavors follow four phases: idea generation, idea development, championing, and integration. In each of these phases, individuals have different needs for the information that social networks should provide. In the first phase, idea generation, the authors argue that weak network features and ties are favorable for inspiration. The second phase, in contrast, requires strong support and tacit knowledge to develop further an idea that strong ties and close peers can provide. The last two phases involve the need for promoting and implementing an idea. This conceptual work integrates different and contradicting arguments in the network literature by emphasizing the importance of time in social networks. In this study, we explore such time effects in the context of social interactions in online communities.

Following Perry-Smith and Mannucci's (2017) conceptual arguments, we investigate different idea phases over time. In particular, we focus on individuals' activities before sharing an idea in an online community to capture the relationship between time-dependent social interactions and idea outcomes. Thus, the first two phases, idea generation and idea development, form the core of our theorizing. The particular order of the phases is essential for innovative idea outcomes. First, individuals get inspired to create ideas and, subsequently, individuals need more focused information to develop their ideas. As a result, we hypothesize a positive relationship between the duration (between inspiration and focus) and idea innovativeness that diminishes when the inspiration and focus period are too far apart. In addition to the time separation and order, we argue that more different phases strengthen the time effect.

Study B uses the same research setting as study A to test the hypotheses. Thus, again, the dataset consists of 18,146 ideas, 19,919 profiles, and 52,663 comments. Instead of the overall accessed information in network position before sharing an idea, we capture an individual's interest allocation over time and identify the time and extent of maximum inspiration and maximum focus. Similar to study A, we measure the innovativeness of an idea. The results of regression analysis support our hypotheses and, thus, also the conceptual work by Perry-Smith and Mannucci (2017). Further, the findings indicate that the effects of social networks on innovative endeavors are indeed time-dependent.

Study C aims to answer the third research question by investigating the ongoing development of an idea and social interactions within an online community. The motivation and findings of the first two studies already underline social interactions' relationship to innovative outcomes in online communities. Further, as described above, prior studies found a variety of social forces that influence community members' behavior (e.g., Chen et al., 2018; Klapper et al., 2021; Ma & Agarwal, 2007; H.-T. Tsai & Bagozzi, 2014; von Krogh et al., 2012). This study explores the open question of whether such social forces are able to not only nudge preferences but influence entire directions of idea developments.

We draw on social impact theory to explain how social influences on idea development in online communities unfold. Social impact theory aims to describe the extent of impact influences have on others (Latané, 1981). Latané (1981) argues that the impact of an influence increases with the source's strength, the number of sources, and the influence's immediacy. In addition to the direct effects, these three components complement each other so that social impact is a multiplicative function of strength, number, and immediacy (Latané, 1981). We argue that social impact theory can be applied to online communities. Feedback, contributions, or suggestions can include different thematic directions. We hypothesize that the three components of social impact theory predict an influences' impact on the idea development in online communities. Further, the unique context of online communities allows theorizing about contingencies that moderate the social impact of influences. Consequently, we introduce four moderating factors: maturity, crowding, persistence, and distance.

For this study, we deemed another research context as ideal to test our hypotheses. We chose the open-source software online community GitHub as it is particularly used for active development on projects with the community. By analyzing 751,412 textual posts of 84 projects

within the community, we clustered posts with similar content and evaluated their impact on subsequent project updates. In doing so, each cluster represents a social influence potentially pulling a project into its direction. According to social impact theory and our hypotheses, the extent to which each cluster influences a project depends on its strength, the number of single influences, and immediacy. We calculated these social impact variables for each cluster along with our proposed online community-specific moderators and control variables on the cluster level. The results of the fixed-effects regression support social impact theory and indicate that social influences impact the direction of idea developments in online communities. The particular context of online communities also provides an extension of social impact theory. We find contingencies (maturity, crowding, persistence, and distance) that further explain how social influences impact others in their decisions. In addition, we explore alternative explanations (agenda, quality, and other influences) that could drive the impact of social influences on the ongoing development direction of ideas.

Chapter 2 Study A

The influence of information depth and information breadth on brokers' idea newness in online maker communities

Abstract

Social networks provide individuals with diverse or redundant information depending on the network structure. Both types of information offer advantages for generating new ideas. At the same time, network structure and network content are independent. As a result, two individuals with the same network position can access diverse or redundant content from their social peers. In this study, we investigate the function of social networks in innovative endeavors given individuals' different kinds of information accessing behavior. In accordance with previous research, we argue that individuals with a broker status access more diverse information through non-redundant network structures and develop, on average, more novel ideas. We further propose that redundancy in content complements brokers' structural non- redundancy by providing familiar knowledge elements and therefore interpretability, while non-redundancy in both content and structure leads to information overload. Thus, we hypothesize that brokers accessing more information depth, and independently, less information breadth generate newer ideas. To test our hypotheses, we collected data from a popular online maker community containing 18,146 ideas, 19,919 profiles, and 52,663 comments. We used topic modeling (Latent Dirichlet Allocation) to extract hidden knowledge elements and social network analysis to identify brokers. In line with our hypotheses, we find that information depth (breadth) strengthens (weakens) a favorable broker position. These findings have implications for the literature on idea generation in social networks and household sector innovation.

Classification

- **Ideation phase:** Idea generation
- **Perspective:** Interaction between network structure and content
- **Data:** Idea descriptions, profiles, and comments of hackaday.io
- **Methods:** Social network analysis, Topic modeling, Hierarchical regression analysis

Publication and Conferences

Published as Resch, Christian, & Kock, Alexander (2021). The influence of information depth and information breadth on brokers' idea newness in online maker communities. *Research Policy*, 50(8), 104142. DOI: 10.1016/j.respol.2020.104142

Presented at Open and User Innovation Conference (OUI) 2019, Utrecht, Netherlands.

Presented at Innovation and Product Development Management Conference (IPDMC) 2019, Leicester, United Kingdom. *Winner of the Thomas Hustad Best Student Paper Award.*

Chapter 3 Study B

Inspiration before focus – time-dependent interest allocation and idea innovativeness in online communities

Abstract

Online communities such as crowdsourcing platforms or user innovation communities are valuable sources for innovation. Community members interact with each other to exchange their ideas. These social interactions express community members' interests which may change over time. Building on prior research, we investigate a leading open hardware online community to analyze how community members' time-dependent interest allocation influences their idea generation. Utilizing the topic modelling technique LDA to extract hidden knowledge elements from the idea descriptions, our findings suggest that it is favorable for community members to focus on specific domains after receiving inspiration to generate innovative ideas. This effect is further amplified for an increasing difference between broad and focused interest. With these findings, we contribute to the literature on IS, innovation, and social networks.

Classification

- **Ideation phase:** Idea generation
- **Perspective:** Time-dependent interactions
- **Data:** Idea descriptions, profiles, and comments of hackaday.io
- **Methods:** Social network analysis, topic modeling, hierarchical regression analysis

Publication and Conference

Published as Resch, Christian, Feiter, Tim, & Kock, Alexander (2021). Inspiration before focus–time-dependent interest allocation and idea innovativeness in online communities. *ECIS 2021 Research Papers.* 103.

Presented at European Conference on Information Systems (ECIS) 2021, Marrakesh, Morocco (virtual). *Nominee for the Best Paper of the Conference.*

Chapter 4 Study C

Social influence on idea development in online communities

Abstract

When individuals freely reveal ideas in online communities, some resonate in the community, and volunteers start contributing, reporting issues, and suggesting ideas. These contributions aggregate to social influences pulling the development in the direction of their needs. Since idea developers face multiple social influences, these influences may affect their decisions about development directions. We draw on social impact theory to understand this critical process that may affect potential innovations and their success or failure. We hypothesize that social impact theory's three factors—strength, immediacy, and number of influence sources—have direct and complementary effects in online communities. The special context of online communities opens the space for theorizing about additional moderating factors (maturity, crowding, persistence, and distance). To test our hypotheses, we collected a dataset of 751,412 timestamped textual posts from GitHub, an open-source software platform. After applying textual analysis to identify latent social influences, we find support for our hypotheses. We further explore alternative explanations (agenda, quality, and other influences) and find consistent results. The results contribute to our understanding of innovation trajectories in online communities, extend social impact theory to a new context, and contribute to recent work in social network literature on complex interactions of network features.

Classification

- **Ideation phase:** Idea development
- **Perspective:** Social influences on the directions of ongoing idea development
- **Data:** Projects, issues, pull requests, and comments of GitHub
- **Methods:** Topic modeling, clustering, fixed-effects, hierarchical regression analysis

Submission and conference

Submitted as Resch, Christian, & Kock, Alexander (2022). Social influence on idea development in online communities. *Under Review*.

Presented at Innovation and Product Development Management Conference (IPDMC) 2021, Milan, Italy (virtual). *Winner of the Thomas Hustad Best Student Paper Award.*

4.1 Introduction

Online communities provide unique sources for new ideas (Dahlander & Frederiksen, 2012) and promise advantages for firms (Fisher, 2019). A prominent example of online communities' success is open-source software development (e.g., von Krogh & von Hippel, 2006). In online communities, individuals freely reveal ideas, combine and remix others' ideas, and collaboratively develop ideas (Faraj et al., 2016; Haefliger et al., 2008; Stanko, 2016; E. von Hippel & von Krogh, 2003, 2006). Understanding the dynamics in online communities, how they create knowledge, and which development directions they choose can offer essential insights for theory and practice. Previous studies investigated individuals' motivation to participate (Acar, 2019; Lakhani & Wolf, 2003; von Krogh et al., 2012) and continuously contribute (Chen et al., 2018; Kokkodis et al., 2020), as well as the origin of good ideas in online communities (Dahlander & Frederiksen, 2012; Safadi et al., 2021). However, prior research often ignored the inner mechanisms of knowledge creation and idea development (Faraj et al., 2016).

Idea development is a social process (Perry-Smith & Mannucci, 2017; Woodman et al., 1993), which also happens in online communities. Online communities underly social norms (O'Mahony & Ferraro, 2007; Shah, 2006; von Krogh et al., 2012), enable social interactions (e.g., Safadi, Johnson, & Faraj, 2020), and knowledge exchange (Faraj et al., 2016). While recent studies acknowledge social influences in online communities (Aral & Walker, 2011; Faraj & Johnson, 2011; Faraj et al., 2016; Wang et al., 2018), they mainly focus on individual social influences such as information on social peers or referral rewards (Dewan et al., 2017; Sun, Viswanathan, & Zheleva, 2020; Wang et al., 2018). However, there are more types of latent social influences in online communities, especially in collaborative idea development. Understanding social influences' effects on online idea development yields the potential to extend prior literature on the inner mechanisms of knowledge creation and social dynamics in online communities (Faraj et al., 2016). As a result, our research question is *How do latent social influences affect the direction of idea development in online communities?*

We draw on social impact theory to develop hypotheses for explaining which direction collaboratively developed ideas take depending on the present social influences. In social impact theory, Latané (1981) describes social influences' impact on a target as a multiplicative function of strength, immediacy, and number of influence sources. We hypothesize that these

effects also apply to online idea development. Further, the unique context of online communities without specific social cues but written communication that is visible for a long time opens the opportunity to extend social impact theory. We propose four moderators that affect the impact of social influences on the direction of idea development. We argue that this impact depends on (1) the maturity of development, (2) the number of simultaneous comments and suggestions (crowding), (3) the timespan an influence exerts (persistence), and (4) an influence's distance to the current idea.

We deem the context of open-source software development as an ideal research context to quantitively test our hypotheses. Open-source software development shows high engagement, social interactions and norms, and collaborative development (O'Mahony & Ferraro, 2007; von Krogh & von Hippel, 2006; von Krogh et al., 2012). Thus, we collected a dataset of the largest open-source software online community GitHub. Our dataset contains the projects created in 2018-2020 that had by the time of data collection (March 05, 2021) over 10,000 stars (likes). These projects contained 751,412 timestamped textual posts (issues, pull requests, and comments) and optional release notes of new software versions. We analyzed the textual data to extract latent knowledge elements by applying Latent Dirichlet Allocation (LDA), a topic modeling technique (Blei et al., 2003; Hannigan et al., 2019; Kaplan & Vakili, 2015; Resch & Kock, 2021). This approach allowed us to measure a content representation for each textual influence. We further identified clusters of these content representations for the time before a project release. These clusters vary in strength, immediacy, and number of influence sources. After measuring the extent to which the subsequent development thematically moves towards the social influence, we find a positive direct effect and a three-way-interaction of the social impact constructs on a project's development direction. In addition, the four introduced moderators further affect this three-way interaction. Furthermore, we subsequently tested alternative explanations for our empirical results. In particular, we identified (1) the presence of a latent agenda, (2) the quality of an influence's suggestions, and (3) the effect of competing influences as potential alternative explanations. Controlling for different variables that capture these three alternative explanations yielded consistent results with our main analysis.

Our findings contribute to the literature in three ways. First, we add to the literature on online communities. Individuals interact and collaborate in online communities resulting in knowledge creation and innovations (Dahlander & Frederiksen, 2012; Faraj et al., 2016; Safadi et al., 2021). We focus on these innovations' collaborative development and show how multiple

social influences pulling in different directions affect development decisions. Second, we build on and extend the social impact theory (Chidambaram & Tung, 2005; Hamilton, Ferraro, Haws, & Mukhopadhyay, 2020; Latané, 1981; Mannes, 2009; Naylor, Lamberton, & West, 2012; Zhang, Li, Burke, & Leykin, 2014). With the direct and interaction effects, we find empirical support that the theory also applies in the context of idea development in online communities. We extend the social impact theory by theoretically and empirically introducing additional context-specific factors that moderate the social impact. Further, instead of a single influence, this study's context includes multiple influences pulling an idea into different directions. Third, we contribute to the social network literature and the origin of good ideas (Björk & Magnusson, 2009). The combination of different social forces underlines recent research describing social networks' function as complex interactions of different and independent network features (Piezunka & Dahlander, 2015; Safadi et al., 2021; Ter Wal et al., 2016).

4.2 Theoretical Background

4.2.1 Online communities

Individuals with shared interests form groups, participate, contribute, exchange information, share ideas, and collaborate in online communities (Faraj et al., 2011, 2016; Lakhani & Wolf, 2003; Safadi et al., 2021). They collectively generate content that yields benefits for other active or passive participants. Online communities such as wikis, innovation contests, Q&A and discussion forums, and open-source software and hardware communities act as a space for knowledge flow, in which value and knowledge generation evolve (Faraj et al., 2016). Online communities create value by developing new knowledge, innovations, and solving problems (e.g., Dahlander & Frederiksen, 2012; Faraj et al., 2016; Fisher, 2019; Franke & Shah, 2003; Jeppesen & Lakhani, 2010; Jeppesen & Laursen, 2009). To organize these value-creating activities, community members develop new governance forms (O'Mahony & Ferraro, 2007; Shah, 2006).

In the past, studies mainly focused on the individuals' motivation to participate in and contribute to online communities (e.g., von Krogh et al., 2012). Contributors' continuous content creation is essential for online communities. Bayus (2013) found that individuals who had successful ideas in crowdsourcing contests in the past tend to create similar ideas afterward, which ultimately could lead to converging content in online communities. In line with this,

scholars investigated how passive community members could be turned into active contributors (Kokkodis et al., 2020) or how IT artifacts motivate community members to continuously contribute (Chen et al., 2018). More generally, prior studies identified that individuals are intrinsically and extrinsically motivated, want to learn new skills, gain reputation, and peer recognition (Faraj et al., 2016; Hausberg & Spaeth, 2020; Jeppesen & Frederiksen, 2006; Lakhani & Wolf, 2003; Ma & Agarwal, 2007; Spaeth et al., 2015; H.-T. Tsai & Bagozzi, 2014; Wasko & Faraj, 2005).

Online communities are social systems with social interactions, social structures, social norms, and social capital (Bauer et al., 2016; Faraj & Johnson, 2011; Faraj et al., 2016; Levina & Arriaga, 2014; von Krogh et al., 2012). Community members collaborate, reuse, and remix other community members' ideas (Haefliger et al., 2008; Stanko, 2016). Prior studies also take a social network perspective to investigate, for instance, creative outcomes in online communities (e.g., Dahlander & Frederiksen, 2012; Resch & Kock, 2021; Singh & Phelps, 2012). Thus, many studies about motivation, contributing behavior, governance, and social interactions directly or indirectly recognized that social influences drive content and knowledge development in online communities. However, we still lack a detailed understanding of how and to what extent social influences impact knowledge flows (Faraj et al., 2016). Building on prior work, we argue that drawing on social impact theory could answer these questions.

4.2.2 Social impact theory

Social impact theory models the influence of sources on targets in a group (Latané, 1981). Latané describes social impact as a function of strength, immediacy, and number of influence sources. The higher each of these three components is, the more impact a social influence has on the target. Latané also postulates that strength, immediacy, and number complement each other so that the total effect is a positive multiplication of the three components. Social impact theory can explain social behavior such as obedience, imitation, persuasion, or conformity. *Strength* describes the importance of the influencing source to the target. For instance, strength could be described by status, authority, or age. In an experimental study, zoo visitors' responses to the zookeeper's requests to not lean on rails were measured (Sedikides & Jackson, 1990). Strength manipulated by clothing and message type yielded significantly higher compliance than lower strength requests. *Immediacy* describes the influence's physical or timely proximity. The impact of the social influence strengthens with increasing closeness of an influencing

source. In the same zoo experiment, the authors also measured the behavior at different times. After the zookeeper left and the less immediate this influence got, the less impact had the zookeeper's request on the visitors' behavior. *Number* represents from how many sources an influence originates. For instance, Milgram, Bickman, and Berkowitz (1969) conducted an experiment in which a group of people stood on the street looking up to a building. The authors investigated how many passing pedestrians stopped to also look up. The number of stopping pedestrians increased with the initial group size standing at the street. In summary, Latané's social impact theory provides a general theory of social impact and governing rules of social forces without claiming to explain the exact process mechanisms when and how social impact is transmitted.

4.3 Hypotheses

Individuals are greatly influenced by others. These social influences are also present in online communities (e.g., Chen et al., 2018; Dewan et al., 2017; Faraj et al., 2016; von Krogh et al., 2012). In this study, we seek to explain how social influences in an online community affect knowledge creation. More specifically, we theorize about the direction ideas take in continuous development in response to the community's social influences. We focus on a typical online community where individuals publicly exchange textual information stored and visible for everyone. Individuals or groups of individuals initially share ideas online. These ideas might resonate with potential contributors who then engage with the project, provide problem solutions, express their needs, request other features, ask questions, and share their ideas. These public interactions can influence the original ideators and ultimately affect further idea development. Our object of analysis is the social influence. We focus on the *impact on development direction*, which we define as the extent to which the subsequent development thematically moves towards the social influence's direction. Figure 6 illustrates our theoretical framework.

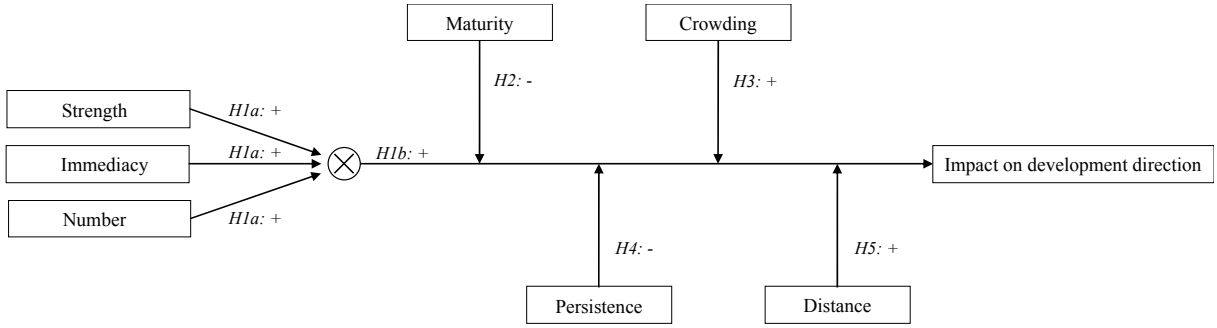

Figure 6. Framework (Study C).

4.3.1 Social impact in the context of online communities

We argue that the social impact theory is suitable for explaining idea development directions in online communities. Although typical social cues lack body language, emotions, or gestures, social structures emerge in online communities with social interactions, governance, cohesion, and social influences (Shah, 2006). In addition, collaboration and feedback affect idea quality in online communities (Zhu et al., 2019). In line with social impact theory, the influence source's social capital determines the strength of these social influences. Individuals' status and embeddedness in the community differ. For instance, opinion leaders emerge, the community core contributes most content, and expertise yields authority (Dahlander & O'Mahony, 2011; Lu, Jerath, & Singh, 2013; O'Mahony & Ferraro, 2007). The status and credibility of influencing community members might affect their persuasion's success (Kruft, Tilsner, Schindler, & Kock, 2019). Individuals gain social capital also in online communities through social interactions, which affects contributions (Wasko & Faraj, 2005). Social capital and prior knowledge contributions are related to community leadership (Faraj, Kudaravalli, & Wasko, 2015). Similarly, formal and informal authority emerge in online communities that affect the behavior between community members (Klapper et al., 2021; Klapper & Reitzig, 2018). Thus, community members' social status represents the strength of their influence. Consequently, we argue that the influences of individuals with higher social capital in an online community have a higher impact on the idea development direction.

Similar to offline social interactions, we argue that an influence's impact decreases with increasing duration since an influence occurred. Timing influences individuals' decisions about suggestions. For instance, the order in which ideas are presented affects their funding (Criscuolo, Dahlander, Grohsjean, & Salter, 2021). Similarly, the timing when influences occur

can affect community owners' or project maintainers' decisions. An influence's immediacy—a small timespan since the influences occurred—is likely to have a higher impact on the decisions of community owners or project maintainers. More recent suggestions or concerns raised by the community are cognitively more present and address current problems. Vice versa, older suggestions might have been included or refused already. Both options imply that the effect of old influences on the future development direction decreases. Further, influences that occurred a long time ago will lose importance and will be covered with newer influences, finally vanish. Further, newer influences might increase the urgency of their respective topics. Thus, we argue that higher immediacy leads to a higher impact on the idea development direction.

The community's suggestions and concerns can be redundant and express similar needs. For instance, different individuals can raise similar points or agree with others' contributions. Increasing engagement of the community members in specific topics raises other community members' and project maintainers' awareness of these needs. Similar to the experiment by Milgram et al. (1969), the more community members point in the same direction discuss and contribute to a specific topic, the more likely it gets that others also look into this direction. This direction can point to a specific problem or wish that the development moves into a direction serving their needs. As a result, with a high number of sources pointing in a similar direction, an influence may seem omnipresent, urgent, and important. Even without the initial consent or plan that an idea should move in this direction, the number of sources can persuade others to adjust the development direction. This reasoning is also in line with the theory of planned behavior (Ajzen, 1991). With a higher number of sources pointing to a similar direction, individuals might face a subjective norm that increases the impact of a social influence. Thus, following social impact theory, a higher number of an influence's sources might lead to a higher impact on the idea development direction.

In sum, we hypothesize that the three social impact factors affect the idea development direction.

> ***Hypothesis 1a.*** *Strength, immediacy, and number of an influence's sources are positively related to an influence's impact on the idea development direction.*

Following social impact theory, we also consider the interaction of the three factors: strength, immediacy, and number. Combining immediacy and number amplifies the urgency and importance compared to every single factor. An influence with a high number of sources has a higher impact on the influence's target if these sources originate recently instead of a long time ago. Similarly, an influence's importance will be increased when a high number of sources hold a high social status within the community. This urgency and importance will be further increased when the influence combines high social capital, high number, and high immediacy. Two strong influences (in the same direction) that emerged recently are likely to yield more impact than one weak influence that emerged a long time ago. With higher dimensions of each social impact theory component, the combined impact on the other community members should increase. We thus hypothesize that strength, immediacy, and number complement each other to describe a social influence's impact on the idea development.

> ***Hypothesis 1b.*** *Strength, immediacy, and number of an influence's sources positively interact to predict an influence's impact on the idea development direction.*

4.3.2 Contingencies of social impact theory in online communities

In addition to the original factors, online communities' characteristics open the opportunity to extend social impact theory. Although social impact theory explains how influences work, the theory does not account for individual personality or situational differences (Latané, 1981). For instance, some individuals might be more influenceable than others. Vice versa, some individuals and their textual posts can be more persuasive than others (Kruft et al., 2019). In some situations, the same constellation of strength, immediacy, and number might yield different impacts on an influence's targets. Similarly, other attributes of an influence are not considered. For instance, influences might differ in how much behavioral change or effort is required (Ajzen, 1991). In addition to social dynamics and social forces, online communities are characterized by membership fluidity, affecting knowledge collaboration (Faraj et al., 2011). Since online community members collaboratively develop ideas over time (Faraj et al., 2011, 2016), the project community's characteristics and influence can differ. The content of online communities' projects evolves over time and the number of active contributors as well as the frequency of their contributions might also change (Kane & Ransbotham, 2016). This

growing maturity and number of simultaneous contributions might affect the attention core community members pay to social influences and thus these social influences' impact on the development direction. Further, online communities facilitate knowledge flow over space and time by storing textual information that become visible to others over a long time. Thus, social influences are also stored and similar influences can persist over time. This persistence might affect the impact of social influences. In addition, open discussions with multiple different contributors having different needs and goals constitutes a special context for social influences. The content of suggestions and social influences can differ from a project's current focus. This distance might affect social influences' impact on future developments. Given these characteristics, we derive maturity, crowding, persistence, and distance as contingencies that affect the impact social influences might have on the development direction of ideas in online communities.

Project maturity may affect social influences' impact on the idea development direction. At the beginning of a new project, the original ideators might want to solve their own needs and ultimately share the solutions with the community (E. von Hippel, 2017). After resonating with the community and collecting initial feedback, the ideators likely show high receptivity for social influences. Positive feedback and peer recognition might initially motivate original ideators to conform and add other users' feature requests. Further, initial ideas are likely to have many opportunities for improvements and different development trajectories as original ideators cannot anticipate or incorporate all user needs ex-ante. Similarly, when an individual or organization decides to freely reveal a project, following subsequent feature requests could build ties with the community and adapt to not envisioned user needs. Further, at the beginning of a community's lifetime, individuals start contributing to generate content. However, with more developed content, an increasing number of individuals start consuming content, but at the same time, opportunities to contribute become more complex and thus lead to fewer contributors (Kane & Ransbotham, 2016). This also indicates that the influence on an idea's development direction is stronger in the early development phases.

In contrast, when a project grows and matures, the impact of social influences might decrease. In mature projects, existing contributors might retain the status quo (Kane, Johnson, & Majchrzak, 2014) or act strategically by negatively peer evaluating newcomers (Klapper et al., 2021). Further, a more mature project might face several hurdles to adopt other users'

suggestions such as bureaucracy, path dependencies, and established governance. As a result, we hypothesize that an influence's impact diminishes with increasing maturity.

> ***Hypothesis 2.*** *The project's maturity negatively interacts with strength, immediacy, and number to predict an influence's impact on the idea development direction.*

Prior studies investigated the effects of *crowding* and workload in the context of problem-solving, idea evaluation, and idea selection (Criscuolo et al., 2017; Haas et al., 2015; Piezunka & Dahlander, 2015). Crowding is the exposure of numerous suggestions in a short period and thus affects and constrains the attention individuals spend on single suggestions (Ocasio, 2010; Piezunka & Dahlander, 2015). Piezunka and Dahlander (2015) found that crowding narrows an organization's attention to idea suggestions, filtering out distant suggestions. Similarly, higher levels of workload reduce the likelihood to favor novel suggestions (Criscuolo et al., 2017), and crowding increases the attention on problems that match individuals' existing expertise in online communities (Haas et al., 2015). This neglect of distant and novel content is likely caused by information overload. Information overload affects contribution behavior in online communities by focusing on and creating simpler messages and ending active participation (Jones, Ravid, & Rafaeli, 2004). Building on this prior research, we argue that crowding affects the impact of social influences in online communities. Information overload could result in focusing primarily on influences with high social impact. Overall, crowding reduces the time available for engaging with each community suggestion, feature request, and overall development. Kruft et al. (2019) found that idea evaluators focus on different cues when an idea's content is scarce. Similarly, we argue that information overload restricts core members attention to the content of suggestions. Instead, they rely on other factors such as the social impact of ideators to filter suggestions. Consequently, we hypothesize that crowding increases the impact of social influences.

> ***Hypothesis 3.*** *Crowding positively interacts with strength, immediacy, and number to predict an influence's impact on the idea development direction.*

Asynchronous communication is an important characteristic of collaborative development in online communities. Preserving textual information allows individuals to catch up with and build their ideas on previous discussions and developments. This characteristic also allows project maintainers to recognize and track suggestions over a longer period. Timely *persistent* influences—similar influences that repeatedly occur over time—might affect the influences' impact on the development direction. On the one hand, persistence could increase an influence's perceived importance. After initial resistance of project maintainers, persistent influences could be more persuasive because they show that a need exists over a long period. On the other hand, persistence could negatively affect a social influence's impact. Similar to the argumentation for immediacy, an influence that persists over a long period might be already included or rejected and thus not relevant for future developments. This negative effect on the development direction is especially relevant for the interaction between the social impact components and persistence. The impact of immediacy is based on similar needs raised in the most recent past. Higher persistence lowers the urgency of recent needs as they already existed before, and community members got used to them. Persistence also implies that the number of influence sources is distributed over a longer period. Thus, the impact of numerous and focused influence sources that imply urgency and importance decreases. As a result, we hypothesize that a longer duration during which an influence is present hinders an influence's impact on the idea development direction.

> ***Hypothesis 4.*** *An influence's persistence over time negatively interacts with strength, immediacy, and number to predict the influence's impact on the idea development direction.*

Influences differ in the direction in which they pull an idea development. Some suggestions might be more similar to a project's content, while others are different. Core project members have to decide which influence they follow. Thus, a social influence's impact on the development direction might depend on the influence's distance to the project. The distance of an influence may lead to benefits and disadvantages that increase or decrease the influence's impact on development directions. On the one hand, more distant suggestions yield the possibility to find better ideas (Afuah & Tucci, 2012; Ehls, Polier, & Herstatt, 2020; Jeppesen & Lakhani, 2010). Crowdfunding projects that show more distinctiveness are more successful

(Taeuscher et al., 2021) suggesting that online communities favor distant ideas. On the other hand, distance implies higher risk, project members have to understand the suggestions, and more distant suggestions show a lower fit with existing competences and code. In the context of crowdsourcing, Piezunka and Dahlander (2015) found that companies searching for new ideas paradoxically tend to filter out distant suggestions. Further, evaluators and problem-solvers favor ideas that are not too novel (Criscuolo et al., 2017; Haas et al., 2015).

However, we argue that problems like the not-invented-here syndrome contrast the collaborative spirit in online communities and that collective filtering and evaluation processes do not discriminate distant suggestions in collaborative online communities as in companies. Especially with high strength, immediacy, and number, a distant influence gains importance, attracts the community's attention, and subsequently impacts the development direction. A distant suggestion might lead to resistance and rejections. However, project maintainers might pay more attention to a distant influence that originates from a source that poses social capital. A distant influence also appears more present with a higher immediacy and number of influence sources that point to a distant direction. This presence can reduce the subjective novelty for community maintainers and thus a potential resistance. In combination, a high number of strong influence sources that took place recently increases the presence and persuasiveness of a distant suggestion. Thus, we hypothesize that the influence's distance complements the original social impact constructs (strength, immediacy, and number).

> ***Hypothesis 5.*** *The distance between the influence and the idea positively interacts with strength, immediacy, and number to predict an influence's impact on the idea development direction.*

4.4 Methods

4.4.1 Context and sample

We chose open-source software development as an ideal empirical setting for investigating our research question quantitatively. Open-source software development and communities have been extensively investigated and show important characteristics that allow us to observe social interactions, which underlines the importance of this research context (e.g., Dahlander & O'Mahony, 2011; Nagle, 2018; O'Mahony, 2003; Spaeth, von Krogh, & He, 2014; E. von

Hippel & von Krogh, 2003; von Krogh & von Hippel, 2006). First, individuals are intrinsically motivated, participate in learning and working with like-minded people, and ultimately freely reveal and share their ideas publicly with others (Lakhani & Wolf, 2003; E. von Hippel & von Krogh, 2006). Second, community members collaborate and thus socially interact to solve problems (Lakhani & Wolf, 2003). The modularity of software projects enables the separation of labor and small contributions by many individuals (Baldwin & von Hippel, 2011; Shah, 2006). Third, open-source software development is very popular among private individuals and companies. Individuals working on public projects can be distributed worldwide, forcing project maintainers for transparent public communication. Fourth, given that social interactions and development progress are constantly saved, this research context offers the opportunity to objectively observe the impact of social influences on idea development directions.

Consequently, we collected a dataset from the largest open-source software online community *GitHub*. GitHub offers many tools helping software developers create, publish, and collaborate on their projects ranging from code hosting, issue tracking, likes, follows, discussions to automatic code reviews. The basic functionality for interacting and collaboratively developing a project are *issues, pull requests,* and *comments*. Issues and pull requests both represent opportunities to contribute an initial suggestion. Both are organized as a typical online forum with one thread for each suggestion. Issues can have diverse content, such as bug reporting, questions, or feature requests. When community members want to contribute actual software code to a project, they open a pull request with their code and a textual description of the changes. Subsequently, pull requests can be accepted (merged) or rejected by the core project members. Both types of suggestions, issues and pull requests, can be commented on to discuss the topics raised or suggested. Further, GitHub also provides the opportunity to optionally publish software releases. The underlying technology of GitHub is *Git*—a distributed version control system that allows to systematically track changes and merge contributions. Each logged change event in the project history, including its timestamp, is accessible through an API that GitHub provides.

Using this API, we obtained relational and textual data of projects, issues, pull requests, comments, releases, user profiles, and their respective timestamps. For popular projects with a vivid and active community, we focused on projects created in 2018, 2019, and 2020 and received over 10,000 likes until our data collection started (March 05, 2021). We used the release timestamps to define project updates and excluded all projects without any releases to

be able to measure the development direction of an open-source software project. Further, we manually checked all open-source software projects and excluded projects with contributions not primarily in English and projects with no interaction between community members and core project members to drive further development. These steps resulted in a unique dataset of 84 projects, 4771 releases, 98,504 issues, 84,404 pull requests, and 568,504 comments.

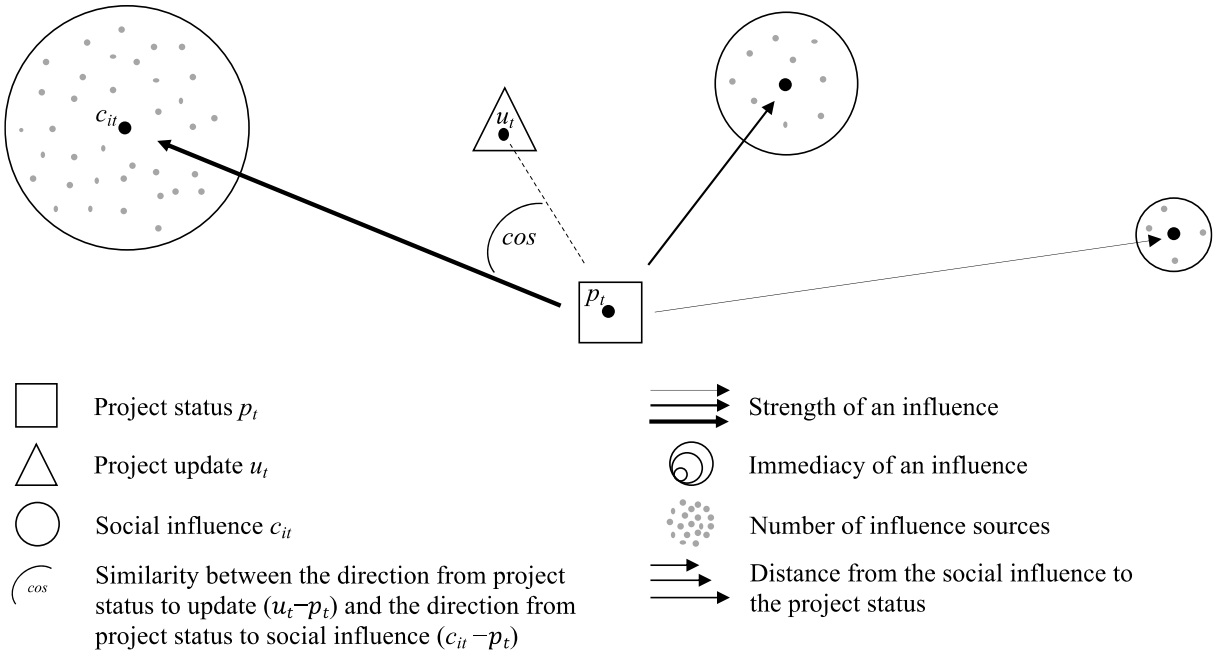

Figure 7. Illustration of social impact, projects, and project updates (Study C).

4.4.2 Measurement

To test our hypotheses, we focused on the textual influences a project community faces over time. Our general approach to identify distinct influences is to extract knowledge elements of the posted texts and cluster these texts. Each cluster represents an influence with similar information that can differ in strength, immediacy, and number of sources. Figure 7 illustrates our approach to measuring social influences and their impact on the development direction of a project considering varying social impacts. For each project update u_t, there is a corresponding prior project p_t and a variable number of social influence cluster c_{it}.

To extract the knowledge from the texts of suggestions or comments, we applied textual analysis and followed prior research in the management literature (Hannigan et al., 2019; Hwang et al., 2019; Kaplan & Vakili, 2015; Resch & Kock, 2021; Safadi et al., 2021; Taeuscher et al., 2021) in utilizing an unsupervised machine learning approach for identifying latent

knowledge topics, called Latent Dirichlet Allocation (LDA) (Blei et al., 2003). LDA's basic assumptions are that an author of a document (in our case, an issue, pull request, or comment) knows several knowledge topics before writing the document and chooses specific vocabulary to express those topics. A document can contain more than one topic, and a word can be contained in more than one topic expressed as a probability that a specific topic is in a document and that a specific word is in a topic. The LDA algorithm's output contains both a document-topic distribution for each document and a topic-word distribution for each topic.

Before conducting the LDA algorithm, we applied common preprocessing steps for preparing the issue, pull request, and comment texts, including setting the text to lower case, removing all punctuations and stop words, lemmatizing, building n-grams, and filtering extreme words with appearing in less than 20 documents or more than 50% of all documents. A minority of documents (e.g., very short comments) got filtered out at this stage so that we derived 751,412 preprocessed documents. After the preprocessing, we used the MALLET software tool (McCallum, 2002) to apply the LDA algorithm with collapsed Gibbs sampling (Griffiths & Steyvers, 2004). Since we did not intend to identify human-understandable topics, we chose an arbitrary topic number of 100 (Vakili & Kaplan, 2021).

With the trained LDA model, we identified each document's topic distribution (issue, pull request, comment) in our corpus, describing a document's content in a 100-dimensional vector. To identify distinct social influences on the project development, we used all documents created during the 180 days before a project update. For each project update, we clustered the respective prior documents. In doing so, we followed prior studies (e.g., Criscuolo, Dahlander, Grohsjean, & Salter, 2017; Haas, Criscuolo, & George, 2015) applying the Ward method with Euclidean distances between the documents' topic vectors (Ward, 1963). Strictly using the stopping rule of Duda and Hart (1973) yielded varying numbers of clusters for each release and project. Each cluster represents one thematic influence on the idea development. Figure 7 conceptually illustrates an outcome of this clustering process in which similar documents form an influence cluster that pulls a project into its direction.

Dependent variable. *Similarity of development direction*. Our dependent variable captures the extent to which a social influence's topical direction is similar to the actual direction of idea development. To measure this variable, we first identified the content representations of the current project status, the project update, and influence, as illustrated in Figure 7. We define

the content representations of a project as the accumulated accepted suggestions (pull requests). Thus, the focus of a project update is represented by the topic vectors' mean p_t of the accepted pull requests between the last $(t-1)$ and the focal (t) project update. Similarly, the current project status is represented by the topic vectors' mean p_t of the accepted pull requests until the last release $(t-1)$. The centroid c_{it} of each influence cluster builds the content representation of each influence. To capture each influence's impact on the direction of idea development, we measured the cosine similarity between the two direction vectors from the project status to the update focus $(u_t - p_t)$ and to each cluster centroid $(c_{it} - p_t)$. This cosine similarity measure ranges from -1 to 1. More similar direction vectors will have higher cosine similarity values (a value of 1 represents an identical direction, a value of 0 an orthogonal, and a value of -1 an opposite direction). This measure captures the extent to which a project development moved in the direction of an influence.

Independent variables. *Social impact - strength*. Leadership in online communities originates from social capital and prior knowledge contributions (Faraj et al., 2015). We argue that the leaders with high reputation send influences with higher strength. In a project community, an individual's social capital increases with a higher presence and number of prior contributions. Thus, we measured the influence's strength by the mean number of prior accepted pull requests of the individuals whose documents are part of the focal influence cluster. This measure represents the expertise and social embeddedness in the community. To reduce the concern that outliers drive the results, we winsorized this variable at the 1st and 99th percentile.

Social impact - immediacy. Immediacy represents an influence's temporal proximity. Thus, our variable immediacy captures the average difference between the update's timestamp and the timestamps of all documents in the focal influence cluster. We moved these negative to positive values. Higher values of immediacy represent a shorter period between an influence and the project update measured in days.

Social impact - number. The third component of social impact theory is the number of an influence's sources. In Milgram et al.'s (1969) experiment, the number of people looking up increased the social influence. In our research setting, textual posts (documents) represent influential sources that point in a certain direction. We clustered similar documents to obtain a single social influence cluster. Consequently, our variable number captures the actual number

of documents in the focal influence cluster. Again, we winsorized this variable at the 1st and 99th percentile to reduce the influence of outliers on our results.

Moderator variables. *Maturity*. The longer a project exists, the more developed the content becomes, affecting knowledge contribution and integration behavior (Kane & Ransbotham, 2016). Thus, the variable maturity measures the days between the initial project creation and a project update.

Crowding. Crowding occurs when individuals face numerous stimuli that cannot be processed and thus lead to information overload (Haas et al., 2015; Jones et al., 2004; Piezunka & Dahlander, 2015). We measure crowding by counting the textual posts within the last 90 days divided by the number of core members that actively contributed during this time frame.

Persistence. We hypothesized that social influences' impact differs when influences are present over a long period. To capture this temporal persistence, we measure the standard deviation of all documents' timestamps in the focal influence cluster. Higher values represent a longer period of influence.

Distance. A suggestion's distance to previously accepted suggestions can affect the tendency of acceptance (Piezunka & Dahlander, 2015). We argue that the distance of an influence alters its impact. Thus, we measure the distance between an influence and a project's status by calculating the cosine similarity between the centroid of the focal influence cluster c_{it} and the content representations of the project p_t. We multiplied this similarity measure with -1 to capture distance instead of similarity (Piezunka & Dahlander, 2015).

Controls. We include control variables at the social influence cluster level for the contributors and the composition of documents in the focal cluster to exclude alternative explanations. First, the possibility of anonymous interaction in online communities may affect the social engagement of individuals. GitHub offers to disclose different personal information (i.e., company affiliation, Twitter account, link to a personal blog, a short biography, personal e-mail address, location, availability to be hired). To account for different levels of anonymous interaction, we follow Safadi et al. (2021) and include the variable *pseudonymity*. In doing so, we counted the number of missing information that contributors did not disclose so that higher values represent less disclosed information. Our variable *pseudonymity* captures the mean value of all document contributors in the focal social influence cluster. Second, the overall experience

on a platform indicates familiarity with processes, communication norms, and quality standards. This experience can affect how the social influence of experienced contributors impacts others. Thus, we include the variable *tenure* as the mean of each contributor's tenure on GitHub when posting a document. Third, the contributors in a social influence cluster can differ in their affiliation to the project. In particular, core project members might discuss some topics more frequently than others. This potential variety in interest over topics can explain the impact of a focal social influence cluster on the development direction. Consequently, we include the variable *share of members*, which captures the share of core members compared to other contributors in a social influence cluster. Fourth, in addition to the cluster composition regarding individuals, clusters can contain different types of documents. Contributions on GitHub are either initial suggestions (i.e., issues and pull requests) or discussions (i.e., comments). A social influence cluster composed of many suggestions may have a higher impact on the development direction than a cluster mainly composed of discussion posts. Thus, we include the variable *share of suggestions* to control for this effect of cluster composition. Fifth, the thematic focus of all influence sources in the focal influence cluster may affect this influence's impact on the development direction. A more specific focus could point to clearer suggestions that are easier to capture, while a broad focus leads to a diffuse influence. We, thus, followed previous research and calculated the Teachman-entropy index (D. A. Harrison & Klein, 2007) with the following formula, in which c_{ij} is the proportion of topic j in cluster i: $cluster's\ topic\ breadth_i = -\sum_{j=1}^{100} c_{ij} * \ln(c_{ij})$. Higher *cluster's topic breadth* values indicate a broad focus in different knowledge domains, while low values represent a focused interest (for similar approaches, see Haas et al., 2015; Resch & Kock, 2021; or Rhee & Leonardi, 2018).

Table 8. Descriptive statistics (Study C).

	Variable	Obs	Mean	*SD*	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1)	Similarity of development direction	81,330	-0.01	0.31	-0.99	1.00	1.000												
(2)	Pseudonymity	81,330	3.66	1.18	0.00	7.00	0.011	1.000											
(3)	Tenure	81,330	2230.05	511.66	2.03	4547.14	0.020	-0.285	1.000										
(4)	Share of members	81,330	2.43	2.46	0.00	25.00	-0.067	-0.153	0.059	1.000									
(5)	Share of suggestions	81,330	0.26	0.24	0.00	1.00	0.091	0.120	0.001	0.015	1.000								
(6)	Cluster's topic breadth	81,330	2.28	0.60	0.01	4.42	-0.035	-0.178	0.227	0.127	-0.019	1.000							
(7)	Maturity	81,330	488.50	257.46	2.91	1137.17	-0.057	0.192	0.182	0.163	-0.052	-0.009	1.000						
(8)	Crowding	72,938	567.13	447.07	11.80	3915.00	-0.084	0.009	0.050	-0.247	-0.084	-0.002	0.144	1.000					
(9)	Persistence	81,330	45.37	12.09	0.00	79.70	-0.052	0.013	0.156	0.197	-0.057	0.072	0.424	0.080	1.000				
(10)	Distance	81,330	0.71	0.22	0.00	1.00	-0.119	0.061	-0.100	-0.033	-0.440	-0.086	-0.001	-0.053	-0.048	1.000			
(11)	Strength	81,330	55.87	75.20	0.00	989.39	-0.066	-0.289	0.112	0.304	-0.010	0.093	0.216	-0.028	0.230	-0.061	1.000		
(12)	Immediacy	81,330	14.09	3.32	0.00	25.49	0.108	-0.045	-0.091	-0.108	0.037	-0.004	-0.372	0.008	-0.582	-0.001	-0.234	1.000	
(13)	Number	81,330	82.89	121.35	1.00	3264.00	-0.060	0.050	-0.059	0.419	-0.037	0.076	0.139	0.052	0.154	-0.157	0.180	-0.099	1.000

Notes: All correlations above 0.009 are statistically significant at the 1%-level. SD = standard deviation.

4.4.3 Estimation strategy

We test our hypotheses using a fixed-effects model to account for the nested structure in our data of projects, updates, and social influences. This estimation approach helps mitigate the concern of certain endogeneity types. We fix all variables at the update level and thus control for all unobserved variables that do not vary across social influence clusters within an update and across updates within a project. A fixed-effects model still allows us to include moderators at higher levels. In particular, our moderators maturity and crowding are measured at the update level and do not change within a social influence cluster.

4.5 Results

4.5.1 Main regression results

Table 8 shows the variables' descriptives and pairwise correlations. In some periods before project updates, no project member actively engaged with the community. As a result, the number of observations for crowding is lower than for the other variables. We standardized all independent variables and moderators to better interpret their coefficients. Table 9 reports the results of the fixed-effects model fixed at the update level. Model 1 contains the single social impact variables without controls. Model 2 includes the three-way-interaction of these variables. In model 3, we add the control variables to the linear social impact variables and model 4 displays the controls together with the three-way interaction of the social impact variables. Models 5-8 separately introduce one four-way-interaction of each moderator: maturity, crowding, persistence, and distance.

In Hypothesis 1, we expected that social impact theory's individual components—strength, immediacy, and number of influence sources—positively affect the development direction in online communities individually and as a multiplicative function. The regression results of models 1-4 all show positive and significant coefficients for the individual effects and the three-way interaction of the variables strength, immediacy, and number, and thus support our first hypothesis. For instance, the results of model 3 show positive individual effects of strength ($b = 0.006, p = 0.001$), immediacy ($b = 0.053, p = 0.000$), and number ($b = 0.011, p = 0.000$) supporting Hypothesis 1a. In model 4, the interaction between these three factors is positive ($b = 0.011, p = 0.000$) and supports Hypothesis 1b. Figure 8 illustrates that a social influence has the most impact on the development direction if all three variables are high.

In Hypotheses 2-5, we theorized about additional moderators in the special context of online communities. The regression results of models 5-8 support all four hypotheses regarding the additional moderators: maturity, crowding, persistence, and distance. The results of model 5 show a negative and significant four-way-interaction term between the three social impact factors and maturity ($b = -0.002, p = 0.000$) and thus support Hypothesis 2. Against Hypothesis 3, we find a negative and significant four-way-interaction term between the three social impact factors and crowding ($b = -0.010, p = 0.000$) in model 6. Hypothesis 4 is supported since the four-way interaction with persistence is negative and significant in model 7 ($b = -0.011, p = 0.000$). These results suggest that higher levels of maturity, crowding, and persistence reduce the impact that social influences have on development directions. Lastly, the positive and significant four-way interaction with distance in model 8 ($b = 0.03, p = 0.010$) supports our Hypothesis 5 and suggests that distant suggestions receive more attention if proposed and backed by influence sources with high social impact.

Table 9. Fixed-effects regression results (Study C).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Similarity of development direction							
Strength	0.006*** [0.002]	0.011*** [0.002]	0.006** [0.002]	0.013*** [0.002]	0.013*** [0.002]	0.013*** [0.002]	0.009*** [0.002]	0.015*** [0.002]
Immediacy	0.053*** [0.002]	0.062*** [0.002]	0.053*** [0.002]	0.063*** [0.002]	0.064*** [0.002]	0.063*** [0.002]	0.065*** [0.002]	0.066*** [0.002]
Number	0.010*** [0.001]	0.015*** [0.001]	0.011*** [0.001]	0.016*** [0.001]	0.016*** [0.001]	0.017*** [0.001]	0.013*** [0.001]	0.007*** [0.001]
Strength x immediacy		0.015*** [0.002]		0.015*** [0.002]	0.018*** [0.002]	0.016*** [0.002]	0.014*** [0.002]	0.013*** [0.002]
Strength x number		0.007*** [0.001]		0.006*** [0.001]	0.007*** [0.001]	0.010*** [0.001]	0.000 [0.002]	0.000 [0.001]
Immediacy x number		0.024*** [0.001]		0.024*** [0.001]	0.028*** [0.002]	0.027*** [0.002]	0.025*** [0.002]	0.015*** [0.002]
Strength x immediacy x number		0.012*** [0.002]		0.011*** [0.002]	0.019*** [0.002]	0.015*** [0.002]	0.014*** [0.002]	0.005** [0.002]
Pseudonymity			-0.005*** [0.001]	-0.005*** [0.001]	-0.005*** [0.001]	-0.006*** [0.001]	-0.004** [0.001]	-0.006*** [0.001]
Tenure			0.000*** [0.000]	0.000*** [0.000]	0.000*** [0.000]	0.000*** [0.000]	0.000*** [0.000]	0.000* [0.000]
Share of members			0.003*** [0.001]	0.003*** [0.001]	0.003*** [0.001]	0.003*** [0.001]	0.002** [0.001]	0.002** [0.001]
Share of suggestions			0.113*** [0.004]	0.113*** [0.004]	0.113*** [0.004]	0.117*** [0.004]	0.115*** [0.004]	0.085*** [0.004]
Cluster's topic breadth			-0.027*** [0.002]	-0.028*** [0.002]	-0.028*** [0.002]	-0.032*** [0.002]	-0.030*** [0.002]	-0.032*** [0.002]
Maturity x strength					0.001 [0.002]			
Maturity x immediacy					-0.009*** [0.002]			
Maturity x strength x immediacy					-0.004* [0.002]			
Maturity x number					-0.001 [0.001]			
Maturity x strength x number					0.00 [0.001]			
Maturity x immediacy x number					-0.010*** [0.002]			
Maturity x strength x immediacy x number					-0.010*** [0.002]			
Crowding x strength						-0.001 [0.002]		
Crowding x immediacy						-0.003 [0.002]		
Crowding x strength x immediacy						-0.006** [0.002]		
Crowding x number						-0.003** [0.001]		
Crowding x strength x number						-0.006*** [0.001]		

Table 9. Continued.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Similarity of development direction							
Crowding x immediacy x number						-0.004* [0.002]		
Crowding x strength x immediacy x number						-0.010*** [0.002]		
Persistence							0.019*** [0.002]	
Persistence x strength							0.009*** [0.002]	
Persistence x immediacy							-0.003+ [0.001]	
Persistence x strength x immediacy							-0.008*** [0.002]	
Persistence x number							0.004 [0.002]	
Persistence x strength x number							0.009*** [0.003]	
Persistence x immediacy x number							-0.008*** [0.002]	
Persistence x strength x immediacy x number							-0.011*** [0.002]	
Distance								-0.013*** [0.001]
Distance x strength								-0.015*** [0.001]
Distance x immediacy								-0.028*** [0.001]
Distance x strength x immediacy								-0.009*** [0.001]
Distance x number								-0.012*** [0.001]
Distance x strength x number								0.002* [0.001]
Distance x immediacy x number								-0.008*** [0.001]
Distance x strength x immediacy x number								0.003** [0.001]
Constant	-0.014*** [0.001]	-0.010*** [0.001]	0.004 [0.010]	0.011 [0.010]	0.010 [0.010]	0.015 [0.011]	0.015 [0.010]	0.040*** [0.010]
N	81330	81330	81330	81330	81330	72938	81330	81330
R-squared	0.016	0.021	0.032	0.036	0.037	0.040	0.039	0.049
F	438.10	235.36	325.33	247.51	159.84	154.94	161.43	204.82

Notes: * p<0.05, ** p<0.01, *** p<0.001. Standard errors in brackets.

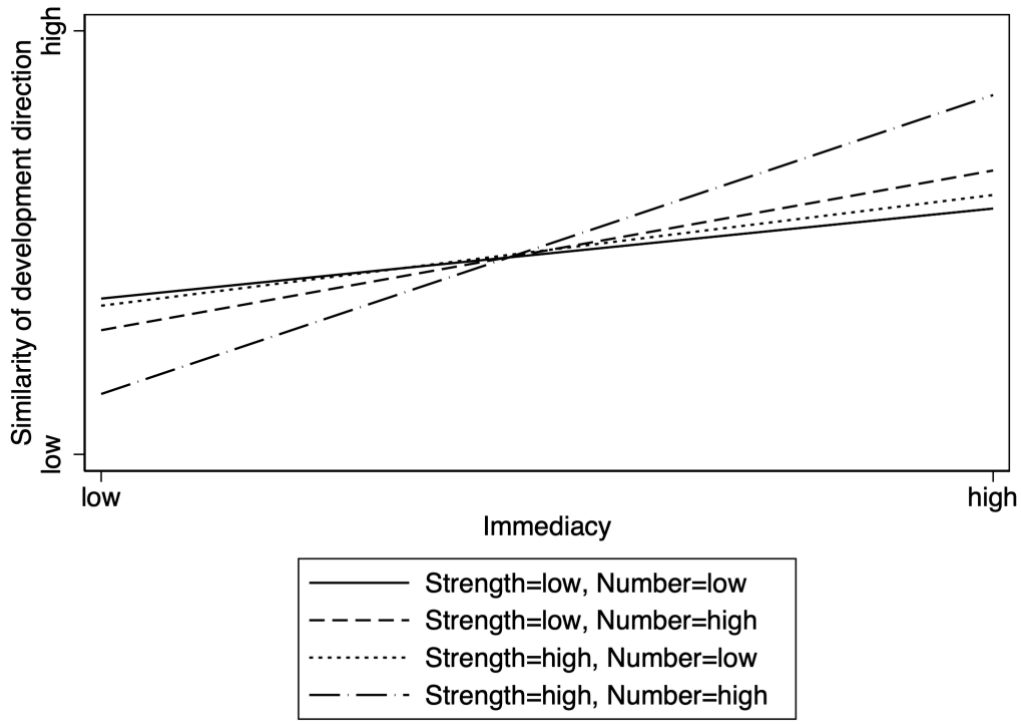

Figure 8. Simple slopes of three-way interaction between strength, immediacy, and number (Study C).

4.5.2 Alternative explanations

Although our estimation strategy with fixed-effects controls for many potential omitted variables, alternative explanations still exist that could drive the correlations of our main analysis regarding clusters' social impact. Thus, we explored potential alternative explanations. In particular, we included and controlled for variables that capture (1) a potential latent agenda, (2) the quality of a cluster's suggestions, and (3) the effect of the other clusters' social influence within a focal update. Table 10 presents the results of exploring these different alternative explanations. Each model includes a different variable to control for a specific alternative explanation. Model 8 also includes all variables as controls with consistent results.

Agenda. A latent agenda for the focus of future development directions could be an alternative cause for the positive correlation between the social impact variables (strength, immediacy, and number) and the direction. Although open-source software projects embrace contributions and external ideas, it is possible and to a certain extent likely that a project has set certain goals and overall directions in which the development moves. Such an agenda would determine the topics of suggestions that will be included in future updates. Thus, a social influence cluster's impact

could arise from a match with the agenda instead of a real influence that alters the development direction. In addition, the awareness of an agenda could motivate individuals to contribute especially to the agenda's topics so that a cluster (with high strength, immediacy, and number) forms around these topics. Further, more embedded community members are likely to be aware of and follow an agenda. These community members' social capital and opinion leaders could attract more contributors and reinforce the trend towards agenda topics. In sum, an agenda could affect which suggestions and social influences align with the ongoing development direction.

We control for two different perspectives on the agenda effect to identify if the development direction is solely driven by the agenda effect instead of social influences. First, core members' contributions are likely to express content related to the agenda. Thus, we controlled for the distance between the focal social influence cluster and the core member contributions. In doing so, we aggregated all core member contributions' topic vectors of the last 30 days before the update was published. We then calculated the cosine similarity between the mean of these core member contributions' topic vectors and the centroid of the focal social influence cluster c_{it}. We then multiplied this similarity by -1 to derive the variable *distance to member texts*, representing how different the focal influence cluster is compared to the content that core members engage with. Model 1 in Table 10 includes *distance to member texts* as a control variable. In accordance with our argumentation for an agenda effect, we find a negative relationship between *distance to member texts* and the development direction. However, the three-way interaction of the social impact components (strength, immediacy, and number) remains significant and positive. Second, an agenda could be expressed by previous development directions, which can indicate gradual steps towards an overall goal. As a result, contributions in a similar thematic direction to which the project has moved before might point again towards the next direction as the development direction does not change drastically from one update to the next. Thus, we control for the *distance to last update direction*. In doing so, we measured the cosine similarity between the direction of the project to the focal cluster centroid ($c_{it} - p_t$) and the direction the project took towards the last update ($u_{it-1} - p_{t-1}$). Again, we multiplied the cosine similarity by -1 to derive our second agenda variable *distance to last update direction*. Model 2 in Table 10 introduces this variable in addition to the social impact three-way interaction. The negative and significant coefficient of *distance to last update direction* supports our agenda reasoning while again our main effects hold. In sum, the results of introducing both agenda variables in model 1 and model 2 indicate the presence of an agenda

effect but still support our hypotheses that social influences impact the development direction as a function of strength, immediacy, and number of influence sources.

Quality. Another potential alternative explanation is the quality of suggestions in a focal social influence cluster. Similar to the agenda effect, there might be two effects that could drive the correlation between the social impact components and development direction. First, a higher quality of suggestions is more persuasive and could convince core members to move in directions not directly intended. Further, core members have to spend less effort to validate and integrate suggestions of high quality. Thus, there might be less resistance to including new features. Second, high-quality contributions are likely to attract other contributions, which result in a reinforcing cluster with increasing social impact. Vice versa, a cluster with a lot of popularity might increase contributors' motivation to develop high-quality contributions to the focal cluster, which in turn increases the likelihood that the project moves in this direction. Consequently, we introduce three measures to account for the effect of quality. First, model 3 in Table 10 includes the variable *number of files*, representing the average number of files that a clusters' contributors changed for their pull requests. Changing more files indicates a deeper engagement and a certain effort that could result in a high-quality contribution. Second, we measure the average time for a pull request in a focal cluster to be accepted and merged. We argue that the time for accepting a suggestion is an indicator for its quality. The less time core members take to accept suggestions, the more likely these suggestions are of high quality. We transform the variable *average time for acceptance* by taking the logarithm because it is highly skewed. Since not all influence clusters include pull requests, the number of observations for model 4 decreases. Third, we counted the mean *number of prior projects* that contributors in a focal cluster owned before posting a contribution. The number of prior projects indicates experience, which in turn yields knowledge for high-quality contributions. Model 5 in Table 10 includes this variable. The results of models 3-5 in Table 10 support our main hypothesis as the three-way interaction stays positive and significant even when controlling for quality.

Other clusters. Our findings could also be driven by the other influences that exist for a focal update. A single social influence rarely occurs alone. Instead, multiple different influences might compete against each other and pull the development towards their direction. As a result, these other influences might affect the impact of a focal influence. We address this alternative explanation by introducing two additional variables that capture different arguments. First, a focal influence might point to a similar direction like the other present influences. Thus, the

impact of this focal influence on the development direction could also be caused by the social impact of the other influences. Identical influences do not represent separate influences but an influence with likely even more social impact. However, after identifying distinct influences, these influences could point to a similar overall direction but still be different. Thus, we decided to add the difference between the directions in which the focal influence and the other influences pull a project. In doing so, we calculated the cosine similarity between the direction of the project to the focal cluster centroid ($c_{it} - p_t$) and the direction of the project to the mean of the other cluster centroids for the focal update. After multiplying this similarity by -1, we derived our variable *direction distance other clusters,* which is included in model 6. Second, the distance to other influences could affect the focal influence's impact. For instance, different other social influences represent opposing influences on a project and thus hinder the impact of a different focal influence. To control for this effect of others clusters on a focal cluster's impact, we include the variable *distance to other clusters* by calculating the cosine similarity between the focal cluster's centroid and the mean of the other clusters' centroids. Again, we multiplied the variable by -1 to get the distance measure and added it in model 7. The results of model 6 and model 7 show that our main findings on social impact hold when controlling for the effect of other simultaneous social influences.

4.5.3 Supplementary analyses

In addition to exploring alternative explanations, we performed several supplementary analyses and robustness checks. First, our main effect of the social impact three-way interaction holds when not winsorizing our independent variables strength and number. Second, we repeated our main analysis with the same sample constraints that reduced the number of observations for the variable crowding to more rigorously include only observations for which core members were active in the direct period before. The results stayed the same as described in Table 9 with this sample constraint. Third, we tested all models of the alternative explanations as well as our four additional four-way interactions without control variables. Fourth, our reasoning of the first hypothesis also implies that the two-way interactions between each of the three social impact variables are possible. Thus, we performed the three two-way interactions between strength, immediacy, and number including the control variables. The results show positive and significant effects of the interactions between strength and immediacy ($b = 0.013, p = 0.000$) and between immediacy and number ($b = 0.021, p = 0.000$) but no significant effect of the interaction between strength and number ($b = -0.000, p = 0.709$). These additional results

further indicate the complementary effects of the single components and that all three components need to be present. Fifth, we tested our main analysis again by considering and exploring the amount of accepted pull requests that constitute an update. Following the rationale that a social influence's impact should increase for larger update sizes consisting of more texts, we constrained our sample regarding the minimum number of texts that constitute an update. Incrementally increasing this threshold by five (from zero to 30) yields consistent and stronger results regarding significance and explained variance for all models (three-way and four-way interactions) of our main analysis. This let us to explore the number of documents that constitute an update as an additional moderator. Consistent with constraining the sample, this additional interaction with the social impact three-way interaction shows a significant and positive effect. We see this model dependence on and increased model fit due to more information that expresses an update as additional support of our theorizing because social influences can express more impact if an update consists of more accepted suggestions.

Table 10. Regression results for alternative explanations (Study C).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Similarity of development direction							
Pseudonymity	-0.004*** [0.001]	-0.004** [0.001]	-0.005*** [0.001]	-0.010*** [0.002]	-0.006*** [0.001]	-0.004** [0.001]	-0.005*** [0.001]	-0.007*** [0.002]
Tenure	0.000* [0.000]	0.000*** [0.000]	0.000*** [0.000]	0.000*** [0.000]	0.000*** [0.000]	0.000*** [0.000]	0.000*** [0.000]	0.000 [0.000]
Share of members	0.001 [0.001]	0.002* [0.001]	0.003*** [0.001]	0.004*** [0.001]	0.003*** [0.001]	0.002** [0.001]	0.003*** [0.001]	0.002 [0.001]
Share of suggestions	0.110*** [0.004]	0.090*** [0.004]	0.113*** [0.004]	0.139*** [0.005]	0.113*** [0.004]	0.085*** [0.004]	0.113*** [0.004]	0.120*** [0.007]
Cluster's topic breadth	-0.021*** [0.002]	-0.021*** [0.002]	-0.028*** [0.002]	-0.036*** [0.002]	-0.029*** [0.002]	-0.018*** [0.002]	-0.028*** [0.002]	-0.009** [0.003]
Strength	0.013*** [0.002]	0.009*** [0.002]	0.013*** [0.002]	0.009*** [0.003]	0.012*** [0.002]	0.011*** [0.002]	0.013*** [0.002]	-0.006 [0.003]
Immediacy	0.062*** [0.002]	0.049*** [0.002]	0.063*** [0.002]	0.096*** [0.002]	0.063*** [0.002]	0.062*** [0.002]	0.063*** [0.002]	0.078*** [0.002]
Number	0.014*** [0.001]	0.013*** [0.001]	0.016*** [0.001]	0.017*** [0.002]	0.016*** [0.001]	0.016*** [0.001]	0.016*** [0.001]	0.012*** [0.002]
Strength x immediacy	0.015*** [0.002]	0.011*** [0.002]	0.015*** [0.002]	0.004+ [0.002]	0.015*** [0.002]	0.015*** [0.002]	0.015*** [0.002]	0.001 [0.002]
Strength x number	0.006*** [0.001]	0.005*** [0.001]	0.006*** [0.001]	0.006*** [0.001]	0.007*** [0.001]	0.006*** [0.001]	0.006*** [0.001]	0.004** [0.001]
Immediacy x number	0.024*** [0.001]	0.019*** [0.001]	0.024*** [0.001]	0.031*** [0.002]	0.024*** [0.001]	0.024*** [0.001]	0.024*** [0.001]	0.025*** [0.002]
Strength x immediacy x number	0.011*** [0.002]	0.009*** [0.002]	0.011*** [0.002]	0.006** [0.002]	0.011*** [0.002]	0.011*** [0.002]	0.011*** [0.002]	0.004* [0.002]
Distance to member	-0.047*** [0.005]							-0.072*** [0.009]
Distance to last update direction		-0.230*** [0.004]						-0.221*** [0.004]
Number of files			0.000 [0.000]					0.000 [0.000]
Average time for accept *(ln)*				0.003*** [0.001]				0.002** [0.001]
Number of prior projects					-0.000** [0.000]			-0.000* [0.000]
Direction distance other clusters						0.053*** [0.004]		0.000 [0.006]
Distance to other clusters							0.000 [0.005]	0.039*** [0.010]
Constant	0.055*** [0.011]	0.238*** [0.010]	0.004 [0.010]	-0.020*** [0.016]	0.005 [0.010]	-0.047*** [0.011]	-0.033*** [0.012]	0.223*** [0.020]
N	81330	77821	81330	58058	81330	81318	81318	56175
R-squared	0.038	0.089	0.036	0.053	0.036	0.038	0.036	0.105
F	236.72	566.71	228.71	237.99	229.20	239.99	228.47	313.86

Notes: + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. Standard errors in brackets.

4.6 Discussion

This paper follows the question of how latent social influences affect idea development directions in online communities. This question addresses a relevant but unanswered gap in the online community and social network literature. Understanding the social dynamics that drive idea development in online communities allows for steering these collaborative efforts. In addition, these social dynamics can explain which innovation trajectories are pursued in online communities. By identifying latent social influences through textual analysis in a large collaborative online community, we show that social influences affect decisions on development directions. We draw on social impact theory to explain the extent to which social influences affect this development. We further propose four additional moderating factors. Our results support the direct and multiplicative effect of the three original social impact factors: strength, immediacy, and number of sources. We also find that project maturity, crowding, and persistence weaken this impact, while the distance of an influence to the project strengthens this impact. Surprisingly the four-way interaction with crowding show a negative coefficient against our hypothesized effect. This finding implies, that information overload due to crowding also decreases individuals' attention to social cues such as social capital. In addition, an increasing number of influence sources poses an additional cognitive burden and thus additional information overload when project members already face the negative effects of crowding.

4.6.1 Theoretical implications

This study's findings contribute to the literature in three ways. First, we add to the literature on online communities. While scholars acknowledge the influence of social forces in online communities (Aral & Walker, 2011; Faraj & Johnson, 2011; Faraj et al., 2016; Wang et al., 2018), prior studies mainly focused on motivations to participate and contribute (Kokkodis et al., 2020; Spaeth et al., 2015; von Krogh et al., 2012). Studies investigating social influences consider single influence sources or individuals' influenced behavior. For instance, prior contributions include that organizations' rejection of distant ideas amplifies with an increasing number of influences (Piezunka & Dahlander, 2015), linguistic assimilation leads to tie formation and reoccurring contributions (Piezunka & Dahlander, 2019), information about social peers and referral rewards affect individuals' referral and purchasing behavior (Dewan et al., 2017; Sun et al., 2020; Wang et al., 2018), and positions in the community, as well as access to information, favors novel contributions (Resch & Kock, 2021; Safadi et al., 2021).

However, online communities also offer a place for collaborative idea development. When an idea is initially revealed in an online community, it may still represent a prototype that others cannot directly implement to solve their problems. However, the idea can resonate in the community, and other interested volunteers contribute knowledge and feedback regarding their own needs. The idea develops and matures over time (Kane & Ransbotham, 2016) and social norms and governance emerge (Bauer et al., 2016; O'Mahony & Ferraro, 2007; Shah, 2006; H.-T. Tsai & Bagozzi, 2014). Developing the idea further becomes a collective effort. In such an ongoing development, multiple influences occur simultaneously and across time. Our findings suggest that a community's social forces influence the development trajectory that a project takes. In particular, this study's findings suggest that social impact theory with its three components strength, immediacy, and the number of influence sources explains to which extent other contributors affect an idea's trajectory.

Further, our study adds to the internalization and generation of explicit knowledge flows in online communities (Nonaka & von Krogh, 2009). Majchrzak, Malhotra, and Zaggl (2020) discovered a self-organizing process in online communities. As a result, community members developed collaboratively novel and useful ideas. This study suggests a mechanism to further explain how such knowledge flows unfold. Social influences determine if and to what extent knowledge gets integrated by others and thus shapes the ongoing development of innovative efforts. In addition, using social influences as stimuli to drive a community in a specific direction could mitigate the risk of content convergence (Bayus, 2013). The introduced moderators further help understand how knowledge flows and shapes innovative efforts in online communities. Crowding has been shown to affect the attention on ideas (Haas et al., 2015; Piezunka & Dahlander, 2015). Our findings add to prior studies by showing that crowding affects another point along an innovation journey by decreasing the impact of social influences. Further, social influences' impact tends to decrease when projects become more mature, or an influence prolongs over time. Lastly, distance also affects idea selection or funding decisions (Criscuolo et al., 2017; Piezunka & Dahlander, 2015; Taeuscher et al., 2021). In this study, social impact might be a potential countermeasure to decrease the risk of sorting out distant ideas.

Second, we build on and extend the social impact theory and thus contribute to social influence literature. Instead of explaining micro mechanisms, social impact theory is rather broad, explaining social influences' overall effect on targets (Chidambaram & Tung, 2005; Hamilton

et al., 2020; Latané, 1981; Mannes, 2009; Naylor et al., 2012; Zhang et al., 2014). Our findings support the direct effects of the three social impact factors. In addition, we add to this conversation by finding a positive interaction between the three factors. We further theorized about additional moderators specific for online communities' characteristics and found statistical support for all four moderating effects: maturity, crowding, persistence, and distance. These additional moderators extend and provide boundaries to social impact theory. Social influences do not always have the same impact on a target. Instead, our findings suggest that the impact depends on further characteristics of the target (i.e., maturity), the environment (i.e., crowding), and the influence itself (i.e., persistence and distance). Furthermore, our research context opens paths for new conceptional theorizing in the literature on social influence. Our findings suggest that social impact theory also applies to a virtual setting that misses many typical social cues. This context includes individuals who want to interact and develop ideas socially. This self-selection excludes personality traits such as extreme predispositions that could be detrimental for investigating social influence. As a result, individuals may have a higher receptiveness for influencing factors. We further consciously increased this effect through our sample selection of the most popular projects in the community. Furthermore, our research setting also allowed us to investigate social influences without interfering and multiple simultaneous influences. Our main findings and the exploration of alternative explanations help understand how social influences unfold in the context of multiple influences that potentially compete against each other. In doing so, we suggest that social impact theory also describes the impact of influences in a multi-influence environment and is thus extensible to a variety of complex social situations.

Third, we contribute to the social network literature. Our study emphasizes the importance of social interaction for creating knowledge (Durmuşoğlu, 2013; Faraj et al., 2011; Perry-Smith & Mannucci, 2017). The findings also indicate that different influence factors in a social network interact (Johnson et al., 2015; Ter Wal et al., 2016). For instance, network actors may independently be connected to many other network actors or actors with high social capital. These interactions can also vary over time. Combining these factors in a network helps explain the effect that social networks have on innovative endeavors. Furthermore, considering immediacy includes and emphasizes time-dependent and repeating social interactions (Soda, Mannucci, & Burt, 2021). Thus, this study suggests that time is an important dimension to explain influences of and in social networks. Finally, we apply methods that allow us to measure

the latent content within the social interactions. Prior studies investigated the combination of social networks and the content in these networks and found complementary effects (Resch & Kock, 2021; Safadi et al., 2021; Wang et al., 2014). With this approach, our findings suggest that the effect of social ties depends on their thematic direction and, vice versa, the content and knowledge transported via social interactions have different impacts depending on the social influences these ties have.

4.6.2 Managerial implications

This study also reveals implications for practitioners. Engaging and managing online communities and crowdsourcing offer competitive advantages (Dahlander, Piezunka, & Jeppesen, 2019; Fisher, 2019). Many ideas originate in online communities, and firms increasingly depend on solutions developed by volunteers outside their organization. In late 2019, Nat Friedman, CEO of GitHub, underlined this trend in his annual opening keynote:

> *"In fact, today, 99 percent of all new software projects have open-source dependencies. So, whether you're working in a big company or a startup, or you're a scientist or a researcher or a student, you rely on open source, and you rely on the people who build it—all around the world, strangers that you don't know. […] If you told someone 20 years ago that by 2020 the dominant paradigm for software development would be strangers volunteering for free online and that everyone would just download their code and put it in almost every product, they would have said, you're crazy, that's not gonna happen, software is written by big professional companies. – But that's the world we are in."*

Despite online communities' importance for external search (Ehls et al., 2020), firms struggle with engaging crowds (Dahlander & Piezunka, 2020) and underestimate user innovators (Bradonjic et al., 2019). Our findings offer three recommendations for managing efforts in online communities. First, awareness of how social influences affect the decisions for future developments may reduce the risk of biases when maintaining an online community. Second, the more a firm depends on others' projects and the more critical these dependencies are for its products, the more likely it will engage in the project's community the firm depends on to safeguard its interests. This study provides insights on how influences have a greater impact. To increase their impact on development directions, companies' employees contributing to an external open-source project should build up social capital in the community and convince

many other volunteers of their interests. Third, in combination with Majchrzak et al. (2020) work, crowds self-organize the creation of novel and useful ideas with the right stimulus. Developing and maintaining an online community with free communication possibilities increases the likelihood that social influences act as stimuli for the process of creative idea generation.

4.7 Limitations and Future Work

This study has limitations that also suggest a potential for future studies. First, choosing our dataset affects our findings' generalizability to other online communities or even other projects on GitHub. We intentionally chose the most popular projects regarding likes to obtain socially active communities. This selection could bias our results so that smaller and less popular community projects react differently to social influences. However, we think that our core arguments also hold in other communities, and we encourage additional studies to investigate the social impact on idea development in other contexts. Second, there might be other variables affecting the extent to which social influences impact individuals in communities. Although we include information about the individuals with the variables *pseudonymity* and *tenure*, there might be additional personal traits and characteristics that influence both the persuasiveness and receptibility for social influences of individuals (Kruft et al., 2019). By integrating additional information, future studies can build on our findings and further uncover influence mechanisms in online communities. Third, although we explore and control for three different alternative explanations, endogeneity cannot be ruled out entirely. Thus, we encourage future studies to build on our findings and ideally conduct experiments in which social influences can be manipulated regarding strength, immediacy, and number of influence sources to clearly identify a causal relationship.

Social influences in online communities will affect future research directions. For instance, online communities developing ideas and products may come to a point where diverging views on future development create social influences that split the community. He et al. (2020) study how communities resolve these disputes. An in-depth analysis of the inner mechanism that leads to these disputes can offer valuable insights to prevent potential community deaths. Here, social influences could explain the emergence and prevention of disputes. Other interesting research avenues include many aspects of forming and growing a community and how social

influences affect this process. For instance, many individuals start an open-source project to fulfill their own needs, which subsequently resonates in the community. The community's social influence might lead the original creators to stay in the community, spend more time and effort into the development, professionalize processes, and ultimately leave the project. Vice versa, the original idea owner's reactions to social influences that originate from the community could increase participation and encourage sharing feedback, needs, and contributions. Missing feedback could stop individuals from contributing (Piezunka & Dahlander, 2019). Lastly, future studies could investigate how social influences in the community affect other volunteering individuals and thus the community itself in addition to core members.

Chapter 5

Discussion

This dissertation aims to shed light on the influence of social interactions on innovative endeavors in online communities. To achieve this goal, I provided an overview of the literature and identified research gaps that led to three research questions about different angles along the journey of an idea. Subsequently, one empirical study was conducted for each research question. While all three research studies contain their individual contributions to the literature, this chapter discusses this dissertation's overall contribution that arises from the combination of each study and its different angle and approach. This combined view also opens the path for future studies that could build on this dissertation's findings and contributions.

5.1 Conclusion

This dissertation investigated social interactions and their relationship with innovations in online communities. Online communities provide a great opportunity to source innovations. Across domains, individuals freely reveal ideas and voluntarily contribute knowledge. At the same time, social interactions and social forces exist in online communities that affect community members' behavior. To better understand the process of idea generation and development embedded in this social context, I posed three research questions that focus on social network structure and content, the time-dependence of social interactions, and the impact of community influence.

Following the first research question on the interplay of network structure and network content, study A emphasizes the necessity of a differentiated view on social networks. The study's empirical results indicate independent and complementary effects of network structure and content. In particular, study A reveals that brokers, while accessing diverse and non-redundant social information, benefit the most from the familiar content of their peers. The combination of broker status and high information breadth yields advantages for generating new ideas. A theoretical explanation for these results includes the need for high interpretability when

accessing non-redundant social information. In contrast, information breadth cognitively burdens brokers with too much information. This information overload is detrimental to brokers' ability to generate new ideas.

Regarding the second research question on time-dependent effects of social interactions on innovative outcomes in online communities, study B confirmed that innovations are influenced by different stimuli within a social network that take place at different points in time. We measured the time between maximal inspiration and maximal focus. Study B's empirical results show that accessing diverse content before focusing on similar topics is positively related to idea innovativeness. The significant inverted u-shape relationship suggests a diminishing effect of the duration between both maxima. Further, this effect is moderated by a high variation between inspiration and focus. As a result, both phases, inspiration, and focus, should be distinct (high variation) and follow each other. In sum, we found that time-dependent effects exist in social networks.

Following the third research question, the empirical results of study C strongly indicate the presence of social influences in online communities and that these influences impact the direction of ongoing idea developments. Social impact theory guided the study's theorizing and methodical approach. We analyzed the texts of individuals contributing to a project on GitHub and captured the directions that projects went by using the content of accepted suggestions. We derived different social influences by clustering texts with similar content and extracted variables that capture the components of social impact theory (strength, number, immediacy) and additional moderating effects. The results of the fixed-effects regression support the main hypothesis and indicate that social influences are present in online communities. Further, social impact theory explains the extent to which projects are influenced, and the special context of online communities extends social impact theory by showing that projects are less influenceable when they are more mature, when crowding occurs, or when influences are more persistent. In addition, core project members are less likely to filter out distant suggestions when they express high social impact.

Overall, all three studies identify social interactions as potential drivers of innovative endeavors. Analyzing the content of these interactions helps enhance the understanding of the inner mechanisms in online communities. The different angles that this dissertation's empirical studies take contribute to a more comprehensive understanding of the different phases that ideas

pass and the involved social forces. The empirical results indicate that these social forces shape ideas and innovative projects before and after the ideas are initially generated and shared.

5.2 Implications for Research

Answering different research questions, each study of this dissertation offers individual contributions to the literature. The combination of the research questions and the respective research studies provide insights from different angles on the overall journey of an idea in an online community, from inspiration, idea generation, and elaboration to the direction of further development steps within the community after sharing the idea. Thus, in addition to the implications of each study, this dissertation, as a whole, offers contributions to the literature on online communities, social networks, and also to user innovation literature. In the following, I elaborate on these overall contributions. The first two contributions are about the literature on online communities. The third and fourth contribution focus the literature on social networks. Lastly, the fifth contribution covers more generally the literature on user innovations.

First, all studies recognize active, innovative behavior in online communities that is influenced by social dynamics and interactions. Prior studies on online communities and crowdsourcing highlight the innovative potential that originates from volunteers sharing their knowledge in a virtual space. Innovations are omnipresent in online communities, and study contexts include knowledge sharing (Chen et al., 2018), open-source software (He et al., 2020), crowdsourcing campaigns (Piezunka & Dahlander, 2019), ideation platforms (Jeppesen & Lakhani, 2010), 3D printing (Flath et al., 2017), design communities (Bauer et al., 2016), extreme sport (E. von Hippel & Kaulartz, 2021), or music communities (Dewan et al., 2017). Modern web technologies allow individuals to interact, collaborate, and build on others' work (Baldwin & von Hippel, 2011; Faraj et al., 2011, 2016; Stanko, 2016). Further, communities develop social cohesion and governance structures (Bauer et al., 2016; O'Mahony & Ferraro, 2007; Shah, 2006; H.-T. Tsai & Bagozzi, 2014). Researchers also focused on the social embeddedness of members in the community (Dahlander & Frederiksen, 2012; Safadi et al., 2021). This dissertation builds on and adds to this research stream. All three studies underline a relationship between social interactions and innovative outcomes. Study A suggests that the social network position in a community is essential for generating new ideas. In addition to that, study B highlights the importance of when community members interact. Study C shows that other

community members' social influences on a project impact its further development direction. So, social dynamics are present in online communities and affect innovative endeavors within them.

In addition to the general connection between social interactions and innovations, the research studies of this dissertation point to the direction that social interactions shape innovations in their content and newness. This direct impact on innovative behavior adds to the literature on social nudging in online communities. Recently, Dewan et al. (2017) found that members' listening behavior in an online music community is influenced by favoriting behavior of the community and even more from direct peers. As another example of social nudging in online communities, Wang et al. (2018) show that community members are socially nudged by their peers when providing ratings. This dissertation also contributes to this line of research by showing that social influences affect innovative outcomes. While study C explicitly investigates social influences in online communities, the first two studies also demonstrate that information gathered from peers has an impact on community members' innovation behavior.

Second, this dissertation contributes to the literature on contribution behavior in online communities. Individuals are often intrinsically motivated to be part of a community and to share their knowledge (Lakhani & von Hippel, 2003; Lakhani & Wolf, 2003; von Krogh et al., 2012). It is crucial for a community to at least sustain the quantity and quality of member contributions. For instance, Bayus (2013) points out the challenge of maintaining the supply of qualitative ideas because ideators with successful ideas in the past tend then to generate similar ideas. Thus, prior studies investigated different aspects of contributions. In addition to intrinsic motivation (Hausberg & Spaeth, 2020; Lakhani & Wolf, 2003), identity aspects, gratifications, and community commitment are reasons for individuals to participate in and contribute to online communities (Bagozzi & Dholakia, 2006; Bateman et al., 2011; Ma & Agarwal, 2007). Chen et al. (2018) studied how IT artifacts (i.e., badges, likes, and comments) increase the number of contributions over time. Piezunka and Dahlander (2019) studied the behavior of contributors in idea crowdsourcing campaigns after their first submission was rejected. They found that the contributors' willingness to submit additional ideas after an initial rejection depends on the level of feedback; so, the interaction with the contributor. Another effect of interactions is the novelty of contributions (Hwang et al., 2019; Safadi et al., 2021). This dissertation adds to this stream of research by showing that contributions (i.e., idea generation and development direction) get influenced by social interactions and the content provided by

social peers. As a result, social networks and interactions play an important role in preventing community stagnation and maintaining the quantity, quality, and novelty of contributions.

This dissertation's implications on contributions go beyond individual contribution behavior. The single studies' findings suggest information overload when receiving too much non-redundant information, which adds prior work on crowding (Haas et al., 2015; Piezunka & Dahlander, 2015). In particular, study A indicates that the information overload of crowding also depends on the non-redundancy of social information. Piezunka and Dahlander (2015) found that crowding increases the negative effects of accepting distant ideas. Study C suggests that crowding also reduces the effect of social influences with high social impact. Furthermore, study C introduces a theoretical view on joint contributions instead of focusing on single individuals.

Third, this dissertation adds to the current and ongoing conversation in the literature on social networks about the relationship between network structure and network content. In the past, studies traditionally assumed an inherent link between structure and content (Aral & Van Alstyne, 2011; Burt, 2010). However, prior research and the studies of this dissertation found independent and complementary effects (Moreira et al., 2018; Piezunka & Dahlander, 2015; Rodan & Galunic, 2004; Schillebeeckx et al., 2019; Wang et al., 2014). While study A explicitly focuses on the first research question on the interplay of network structure and content, all three studies include theoretical arguments and methods to include the content of social interactions. This is in line with recent studies that concentrate on the inner mechanisms of social networks and the information they provide. Network features' effects depend on various factors such as the information diversity that network actors encounter (Moreira et al., 2018), team members' expertise (Schillebeeckx et al., 2019), managers' access to heterogeneous knowledge (Rodan & Galunic, 2004), the attention brokers allocate to their direct peers (Rhee & Leonardi, 2018), and the combination with the independent topic network (Safadi et al., 2021; Wang et al., 2014). This dissertation contributes to this conversation by integrating the actual information flow of social interactions in all three studies. While the first two studies measure the information that individuals access from their direct peers, study C focuses on others' influences on projects that arise by expressing their needs. The studies' findings suggest that capturing the actual content that flows in social networks is essential to understanding the function of social interactions on innovative endeavors.

In addition to integrating content separately and complementary to structure, the combination of non-redundant and redundant information plays a role in recent literature and all three papers of this dissertation. Ter Wal et al. (2016) find that the combination of redundant and non-redundant information offers benefits in investor syndicate networks. Safadi et al. (2021) show that social embeddedness (redundancy) combined with topic marginality (non-redundancy) yields novel ideas. This finding supports the results of study A in which social non-redundance (broker status) combined with content redundance (information depth) benefits idea newness. Study B integrates the combination of redundancy and non-redundance with a separation of time. Taking a different approach, the cluster sizes in study C represented by the number of influences capture a content redundancy of social interactions. At the same time, the study outlines how non-redundancy in terms of distance affects idea development when combined with high social impact. Overall, this dissertation's studies indicate that familiarity or social impact as redundancy influences the effects of non-redundancy.

Fourth, by taking a time-dependent perspective on social interactions, this dissertation also adds to the social network literature and answering a call for taking network content and dynamics into account (Faraj et al., 2016; Sundararajan et al., 2013). Contributions of online community members change over time (Chen et al., 2018; Kane & Ransbotham, 2016), and time-dependence might resolve tensions of seemingly contradictory arguments in the social network literature about redundant and non-redundant information (Mannucci & Perry-Smith, 2021; Perry-Smith & Mannucci, 2017). While study B explicitly investigates and formulates hypotheses about time-dependent social interactions, study A implicitly integrates this view by calculating time-dependent network positions for individuals to capture social interactions during the idea generation period before an idea upload. Further, study C includes time effects of social interactions by introducing maturity as a contingency for the impact of social influences. In sum, the effects and impact of influences in social networks depend on when they happen during creative processes and project lifetimes. Consequently, time is an essential factor in the function of social networks as a facilitator for innovative endeavors.

Fifth, as a result of this dissertation's research contexts, there are contributions to the user and household sector innovation literature. Both research contexts, the online communities hackaday.io and GitHub, contain voluntary individuals who create ideas and innovations and ultimately reveal them for free on these platforms. In addition to the research on open-source software (e.g., Benlian & Hess, 2011; He et al., 2020; Nagle, 2018; Thummadi & Paruchuri,

2021; von Krogh & von Hippel, 2006; von Krogh et al., 2012), prior user innovations studies already investigated users and lead users in online communities (Autio et al., 2013; Franke et al., 2006; C. D. von Hippel & Cann, 2021; E. von Hippel & Kaulartz, 2021). In particular, users' social positions in online communities are related to their lead userness (Kratzer et al., 2016) or the outcome of their ideas (Dahlander & Frederiksen, 2012). This dissertation directly supports these findings with the results of study A (i.e., broker status' positive relationship with idea newness). Furthermore, all three studies add to the literature by focusing on the social dynamics that shape users' innovative endeavors. Users are probably not always lead users who have already created innovations before joining a community. Instead, their ideation process is shaped by others and others' content over time. Further, the findings indicate what information lead users (brokers) might need to develop novel ideas. Users do not only consume information and get inspired; they also impact others and their idea generation and development by providing feedback or need expressions (e.g., issues, comments, and pull requests).

Overall, this dissertation includes current theoretical research trends combined with the latest methods in management research. During the time of our studies and after publishing the first two, other studies with similar research questions and approaches got published. This underlines the importance of the identified research gaps and directly adds to these new publications. For instance, Mannucci and Perry-Smith (2021) conduct empirical work that supports parts of their conceptional propositions about the time dependence of social network effects on ideas (Perry-Smith & Mannucci, 2017). Safadi et al. (2021) take a similar approach as study A by measuring social network centrality and the centrality within a topic network. Furthermore, topic modeling with LDA as a method creates the opportunity to measure content within social networks without interfering with ongoing conversations (Hwang et al., 2019; Safadi et al., 2021). Thus, the use of topic modeling addresses problems of and adds to the literature on social network studies that are often content agnostic (Aral & Van Alstyne, 2011; Burt, 2010; Piezunka & Dahlander, 2015).

Online communities remain a growing potential source for innovations. With emerging technologies such as 3D printing and other rapid prototyping technologies (Bailey, Faraj, Hinds, Leonardi, & von Krogh, 2022), individuals gain more tools to become innovative and iteratively improve their ideas without the need of a company. With growing knowledge and open-source projects (software and hardware) available online, the barriers are lower to realizing ideas (Baldwin & von Hippel, 2011). Thus, the amount of innovation activities outside

of organizations constantly increases. The possibility that these activities continue to take place in online communities underlines the importance of understanding the inner social mechanisms within online communities. This dissertation provides an empirical view with different perspectives on this phenomenon.

5.3 Implications for Practice

This dissertation also has implications for practitioners. Online communities offer advantages for organizations (Fisher, 2019) and are a potential source for innovations (e.g., Dahlander & Frederiksen, 2012; Franke et al., 2006). In addition to internal ideation platforms (Gamber, Kruft, & Kock, 2021; Kruft et al., 2019; Zhu et al., 2019), organizations can host their own online community, hire intermediaries to engage with external individuals, or engage passively or actively with existing communities (Acar, 2019; Benlian, Hilkert, & Hess, 2015; Boudreau, Guinan, Lakhani, & Riedl, 2016; Jeppesen & Lakhani, 2010; Wessel, Thies, & Benlian, 2017). Community owners should aim to maintain the quality of contributions and to find potential innovations (Bayus, 2013). Especially, open-source software is promising (von Krogh & von Hippel, 2006), and examples such as Linux or RedHat show that this organizational form often outperformed traditional approaches. Today, with the advances in artificial intelligence, data collection and analysis, or cloud computing, new projects can build on existing projects of others to kickstart even complex ideas. At the same time, organizations have a natural interest in the projects they depend on to sustain and fulfill their needs. Vice versa, organizations need to steer and manage their own developments with the help of their community. The findings of this dissertation yield implications for practitioners to deal with online communities.

First, the central topic of this dissertation highlights that online communities are a social entity. Partitioners need to be aware of different social dynamics. Prior research emphasized, for instance, that the way ideas are rejected influences highly if an individual will submit other ideas (Piezunka & Dahlander, 2019). Furthermore, communities develop hierarchies, norms, and governance structures (Bauer et al., 2016; Klapper & Reitzig, 2018; O'Mahony & Ferraro, 2007; H.-T. Tsai & Bagozzi, 2014). This dissertation supports these prior findings. Social interactions and the information received represent social forces that influence innovative endeavors. Further, these social dynamics take place over the course of time. Consequently, organizations should take these considerations into account when engaging with communities.

In addition, this dissertations research context includes voluntary individuals that contribute knowledge and ideas. Private individuals' innovative endeavors often result in innovations that outperform traditional closed approaches or experts (Hienerth et al., 2014; Lifshitz-Assaf, 2017). However, practitioners underestimate user innovations (Bradonjic et al., 2019). Anticipating social dynamics and influences in online communities might help organizations to adapt their strategy to emerging trends (Kaufmann, Kock, & Gemünden, 2020). Similarly, the self-maintaining social structures in online communities might help to follow simultaneously different paths and sequentially (e.g., after updates) increase the commitment and development efforts when the most promising or popular direction emerges (Adner & Levinthal, 2004; Kaufmann, Kock, & Gemünden, 2021; Klingebiel & Adner, 2014). In sum, this dissertation underlines the existence and importance of innovations that originate from private individuals influenced by social dynamics within online communities.

Second, in order to capture the value of online communities, practitioners need to identify opportunities and find novel ideas. Studies A and B suggest that interaction data could predict the newness of individuals' upcoming ideas. Thus, monitoring interactions and social network positions (i.e., high betweenness centrality) in an online community can yield valuable information about where to look for innovative ideas. Such monitoring efforts should also include time dependence and the content of interactions. With this fine-grained information about community members' activities, organizations would be able to screen entire online communities automatically and, as a result, receive an overview of potential innovations that could serve as a filter to reduce the amount of manual work. Recent studies suggested automatic text filtering using text analysis for identifying innovations in the context of user innovations (C. D. von Hippel & Cann, 2021; E. von Hippel & Kaulartz, 2021). In addition to analyzing content in online communities, this dissertation highlights the effects of social interaction. Thus, simultaneously capturing social and content data could add additional value for sourcing innovations.

Third, the findings of this dissertation suggest that organizations could actively influence innovative endeavors within online communities. Organizations might have an interest that many novel ideas emerge or that ideas develop into a direction favorable to the organization. To increase the number of novel ideas, organizations can support community members with knowledge. Hwang et al. (2019) propose that companies should simultaneously host customer support and innovation communities to ensure that community members have the right

information in order to generate innovative ideas. Studies A and B add to this suggestion for practitioners. Supporting information should be provided at the right time and by considering a community member's social network position. In particular, when monitoring interactions and their content, organizations can provide focused information after individuals seem to switch from inspiration to focus. Further, if social interaction data suggests that an individual is a broker and thus receiving non-redundant social information, further information such as recommended contents to explore should rather contain redundant information to decrease the risk of information overload. In addition to providing supporting information, organizations could steer the development direction of ideas. As highlighted in study C, feedback, needs, and comments of community members impact the direction in which ideas get developed. The increasing number of open-source projects facilitates developing complex projects by using third-party dependencies. Some of these dependencies can be essential to the functioning of organizations' products and business models. An organization might also have an interest that these essential dependencies develop and integrate innovations to the specific needs of that organization. In such a situation, organizations pay and assign their own employees to contribute to third-party projects in order to influence according to their interests. The findings of study C suggest that the longer and more active organizations and their employees contribute, the higher their impact on the development will be. However, an organization's impact could decrease with increasing maturity of the project. In sum, this dissertation outlines that organizations can support and steer online communications to influence innovative endeavors.

Fourth, the impact that social interactions have on innovative endeavors in online communities might lead to biases that practitioners should be aware of. In addition to the possibilities to actively steer projects with social influences, in organizations' own projects, maintainers decide on suggested ideas and might also be pulled towards others' social influences. Decision making on idea suggestions in organizations involves potential biases such as ruling out novel ideas due to crowding and information overload (Haas et al., 2015; Piezunka & Dahlander, 2015) or the sequential order in which decisions are made (Criscuolo et al., 2021). Although study C does not make assumptions about the optimal development direction, following the pull of social influences can lead to less favorable outcomes. Similarly, an individual's ideas can be biased towards less novelty when the information provided by the social network leads to information overload or diverse and focused information is missing when needed. As social

interactions influence innovative endeavors in online communities, innovative outcomes might be biased, and organizations should be aware of these potential biases.

5.4 Future Research

While this dissertation adds to the previous studies, it also opens the avenue for further research activities. The argumentation of this dissertation implies that individuals are generally open to social interactions, the information of these interactions, and the resulting social influences. However, the information of social interactions might not always resonate or affect the target. The antecedents and consequences of this situation might be promising future research avenues. Regarding the antecedents of receptivity for social interactions and influences, additional contingencies could affect the function of social interactions on innovative endeavors. For instance, individuals' characteristics such as mood, personal background, or absorptive capacity could influence how the received information is processed. Schillebeeckx et al. (2019) found that the effects of a team's social network position depend on its expertise. Building on study A, expertise could affect how individuals process information from social interactions or what kind of information individuals need from their peers. Individuals who already possess specific knowledge can connect knowledge elements in that area (Dane, 2010) but might not need to connect to others to access this knowledge from an online community's social network. This dissertation's studies could not include individuals' prior expertise and knowledge from outside an online community. However, this information on knowledge and information access could affect how individuals use social networks in online communities and get influenced by them. Similarly, an extreme knowledge heterogeneity in an online community could hinder newcomers from contributing (Kane & Ransbotham, 2016). In addition, social influences could affect individuals' behavioral efforts which influence idea success (Gamber et al., 2021). Further, prior bad experiences with social contacts (e.g., opportunistic behavior) can affect the openness to social interactions. For instance, core members strategically evaluate peers negatively who cannot retaliate so that these core members are perceived as capable by other community members but do not have to fear retaliation (Klapper et al., 2021). While this behavior benefits core community members, it could also prevent newcomers from engaging in the community and opening for being affected by social interactions. Considering the consequences of low receptivity for social interactions and influences, positive effects on creativity and idea generation might not unfold, or additional detrimental consequences to

online communities occur. Reduced innovation activities and new input can lead to cognitive rigidity, community convergence, and eventually, the end of a community lifespan (Bayus, 2013; Dane, 2010; Kane & Ransbotham, 2016). In addition, not anticipating and capturing communities' needs and interests out of social interactions could lead to disputes (He et al., 2020) could impede contributions and volunteers from turning away to spend their time supporting other projects. Building on this dissertation, future studies could focus on the questions of what happens when these social influences do not affect their target and what facilitates the receptibility for social influences.

Beyond the argumentation of community maturity's moderating effect on the relationship between social impact and development direction, communities as a whole could evolve. Kane and Ransbotham (2016) already describe that the complexity of required contributions changes over time, and more developed content hinders newcomers from joining a community. Similarly, Bayus (2013) finds that individuals will submit similar ideas to their previous successful ones, thus identifying a potential problem of converging communities. Building on previous research and this dissertation's studies, changes of communities over time could affect the generation and ongoing development of new ideas. Communities could show higher levels of cognitive rigidity. Thus, over time, online communities would be more or less open to new ideas and social influences from outside the core team. Similarly, such changes could affect the information individuals can actively access or are passively exposed to in the social network and interactions when community members become less likely to share their knowledge. Study A and study B suggest that information access is an essential component for idea generation. Consequently, community changes over time that lead to changes in the availability and access to information through social interactions can negatively affect a community's innovative potential as a whole. In addition, license changes limiting the openness of projects likely lead to less active contributions and hinder future innovation activities as code reuse is restricted. Future studies should investigate the drives for change of a whole community and identify ways to steer, facilitate, or prevent this change.

Further, Perry-Smith and Mannucci (2017) argue that individuals need fluid networks and activate the different networks according to the needs in each phase of the idea journey. Study B focusses explicitly on this theoretical reasoning and empirically shows that a timely separation between inspiration and focus is favorable for innovations. Study A and study C also include the time-dependent effects of social interactions on innovative endeavors. However, this

dissertation's studies still leave space for investigating network effects over time and how individuals can gain the right benefits from social networks at the right time. Regarding network activation (Mannucci & Perry-Smith, 2021), future studies could focus on the cognitive processes that initiate switching from inspiration to focus or vice versa and how to facilitate this switch. Similarly, favorable network positions and complementary information could change over time depending on the situation and prior social interactions.

Furthermore, individuals may work on multiple projects and ideas simultaneously in different stages and, thus, require different information from their social networks (Perry-Smith & Mannucci, 2017). Parallel projects could impede each other. Multiple different ideas in the inspiration phase could lead to information overload (Piezunka & Dahlander, 2015). Individuals may not have time to properly gain focused knowledge for multiple parallel projects in the focus phase. Similarly, maintaining large open-source software problems could involve fixing bugs, discussing feature suggestions, or writing documentation. Different tasks may require different cognitive schemas that, in turn, need different networks. However, there might also be spill-over effects when project maintainers with high expertise in one domain are active in adjacent communities (Dane, 2010). Regarding the impact of social influence on projects, influences on other projects could also impact a focal when these projects are connected via contributors who are active in both projects. Such a social contagion across projects could lead to observing clusters of projects developing in similar directions. This could be observable in open-source software projects when specific trends emerge, such as machine learning or user interface libraries. In such a situation, social influences in one project could spread and also inspire or affect other projects. Future research could study how information of social interactions across multiple parallel or sequential projects inter-exchange.

Lastly, in addition to the benefits of social interactions in online communities for innovative endeavors, the combination of online and offline collaborations could be investigated in future studies. Thummadi and Paruchuri (2021) found location-based agglomeration effects in open-source communities. Thus, innovative endeavors in online communities can lead to offline social interactions, and thus a combination of offline and online collaboration can occur. Building on this insight and this dissertation's findings indicating the innovative potential of online collaboration, questions arise on contingencies when either an online or offline setting is favorable and how combining both settings as hybrid projects can yield benefits and challenges. For instance, hybrid projects might have different access to information breadth and

information depth. Following Perry-Smith and Mannucci (2017), core members could get inspired online by a community but elaborate these ideas in detail offline. However, online communities also express a safe space to express and challenge ideas due to their possible anonymity. Further social influences and biases could be mitigated without typical social cues and hierarchical power, while offline cohesion of core members could lead to less social impact of influences by the community. In sum, hybrid forms of collaborations constitute a potential future research avenue that could enhance this dissertation's findings on the influence of social interactions on innovative endeavors in online communities.

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Declaration of Authorship

The dissertation is provided by me with a list of all sources used. I declare that I have written the thesis on my own – apart from the help explicitly mentioned in it.

The thesis has not been published anywhere else nor presented to any other examination board.

Die Dissertation ist von mir mit einem Verzeichnis aller benutzten Quellen versehen. Ich erkläre, dass ich die Arbeit – abgesehen von den in ihr ausdrücklich genannten Hilfen – selbstständig verfasst habe.

Die Arbeit wurde bisher weder einer anderen Prüfungsbehörde vorgelegt noch veröffentlicht.

Christian Resch

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