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Article

A Systems Approach to Studying Online Communities

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Abstract
Much early communication research was inspired by systems theory. This approach emphasizes that individuals and groups use communication to interact with and respond to their larger environment and attempts to outline the ways that different levels interact with each other (e.g., work groups within departments within firms). Many concepts from systems theory—such as emergence and feedback loops—have become integral parts of communication theories. However, until recently, quantitative researchers have struggled to apply a systems approach. Large-scale, multilevel trace data from online platforms combined with computational advances are enabling a turn back toward systems-inspired research. I outline four systems-based approaches that recent research uses to study online communities: community comparisons, individual trajectories, cross-level mechanisms, and simulating emergent behavior. I end with a discussion of the opportunities and challenges of systems-based research for quantitative communication scholars.

Keywords
digital trace data; online communities; organizational communication; systems theory

Issue
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1. Introduction

In the 1960s and 1970s, communication scholars were enthralled by systems theory. While much of scientific progress has advanced by taking a reductionist approach (Sawyer, 2005), systems theory promised a set of theoretical and methodological tools for understanding how interdependent parts communicating and responding to each other can create an emergent whole. Organizational communication scholars produced foundational works elucidating and expounding how systems theory applied to organizations and groups as "open systems" (Farace et al., 1977; Katz & Kahn, 1966; Rogers & Agarwala-Rogers, 1976).

However, quantitative systems-based approaches failed to live up to their promise. These approaches were hampered in large part by the difficulty of obtaining and analyzing appropriate data. Systems theory fell out of favor as organizational communication took an interpretive turn. Although it is rare for contemporary researchers to explicitly view their work in terms of systems theory, many qualitative and quantitative communication theories and questions have been influenced by systems theory and are amenable to systems theory approaches (Contractor, 1994; Lai & Lin, 2017; Poole, 1997, 2014).

Many of the barriers that made systems theory research so difficult have been greatly reduced in online contexts. We have access to digital trace data of online communities and organizations, with rich, granular, longitudinal data from millions of individuals across thousands of online communities. We also have the computational capacity to store, analyze, and model this data. These advances provide a revolutionary opportunity for researchers. In this article, I identify exciting approaches that researchers have already begun to undertake and I argue that the time is ripe for empirical researchers to turn again to systems thinking, theorizing, and testing.

2. Background

2.1. Systems Theory

Poole (2014, p. 50) defines a system as "a set of interdependent components that form an internally organized

whole that operates as one in relation to its environment and to other systems." Unlike typical statistical approaches, which treat each unit of analysis as independent, systems theory focuses on understanding interdependence. Farace et al. (1977) argue that interdependence is a key feature of organizations, and they define it as "the interlocked, reciprocal, mutually influential relationships among the organization's members" (Farace et al., 1977, p. 17). Early systems theorists hoped that systems theory could be a framework for describing all types of interacting, interdependent systems, from cells and organs to organizations and societies (Poole, 2014).

This focus on understanding interdependence spawned a number of approaches and theories, and it is more accurate to think of systems theory as a set of related theories and frameworks rather than as a single theory. In this section I review three concepts from systems theory that I believe are the most influential and generative for communication scholars: environments, feedback loops, and emergence. For each, I give an example or two of communication research that relates to the concept. Following this, I sketch a brief history of how systems theory has influenced communication research. More thorough treatments of systems theory and its relationship with organizational communication can be found in Lai and Lin (2017) and Poole (2014).

2.1.1. Environments

In systems theory, the environment includes everything outside of a system that is relevant to it (Poole, 2014). The system takes in information and inputs from its environment, which influence the system's behavior. A system's environment includes the interdependencies that the system has with other systems—for example, if a product development group is our focal system, the environment might include the product testing group that it relies on for feedback and information. The environment also includes other aspects of the world that are relevant to the functioning of the system, such as the amount of resources available, regulatory or technological constraints, and cultural contexts. Which aspects are considered part of the system and which are part of the environment depends on where the boundary is drawn around the system, a decision which is largely dependent on the research question (Farace et al., 1977).

Many communication researchers have recognized the importance of external environments on organizations. For example, building on new institutionalism (DiMaggio & Powell, 1983), Lammers and Barbour's (2006) institutional theory of organizational communication outlines the ways that extra- or cross-organizational institutions like norms, beliefs, and routines not only influence communication within an organization but are sustained and reproduced through communication processes.

2.1.2. Feedback Loops

Feedback loops identify aspects of a system that are recursive/circular, leading to "mutual causality" (Contractor, 1994). In other words, the behavior of a system influences the environment and then the environment influences the behavior of the system. There are two primary types of feedback loops: Negative feedback loops are self-correcting, where a system responds to environmental changes so as to maintain homeostasis; positive feedback loops are self-amplifying, where the system amplifies environmental changes (Poole, 2014). The most influential treatment of feedback loops, called cybernetics, focused mostly on negative feedback loops (Wiener, 1948). Cybernetics posits that systems constantly gather feedback about the effects of their actions on their external environment and then adjust their actions in order to keep the system's output in line with its goals. The canonical example of a simple cybernetic system is a thermostat.

Many organizational processes can also be conceptualized as feedback loops, although they will typically be much more complicated than a thermostat. For example, Figure 1 shows a simple version of the spiral of silence theory (Noelle-Neumann, 1974). In this model, people perceive the beliefs of those around them based on who is talking about their beliefs. Those who perceive their own opinions to be in the minority are then less likely to speak about them. This leads to a greater imbalance in who is speaking, and an even greater reluctance of those holding minority opinions to speak out. Thus, the spiral of silence is a positive feedback loop: The initial silence of minority believers begets more silence of minority believers until the only ones expressing opinions are all of one belief.

2.1.3. Emergence

Perhaps the key concept of systems theory is emergence. Emergence is colloquially captured in the adage "the whole is greater than the sum of its parts." Emergence is the idea that, in many contexts, understanding the behavior of the individual components of a system is not enough to understand what will happen at a higher level—that higher-level behavior "emerges" from the interaction between components. In other words, through interaction and interdependence, a system can have different attributes and properties than its component parts (Poole, 2014). Individuals following even simple rules can produce surprisingly complex collective behavior (Sawyer, 2005). Examples commonly given are flocks of birds that appear to move as one organism or ants that build complicated structures and exhibit efficient, non-intuitive foraging strategies (Wilensky & Rand, 2015).

Many interpretive communication theories directly draw on the concept of emergence. Most notably, work on communication constitutes organizations (CCO) and

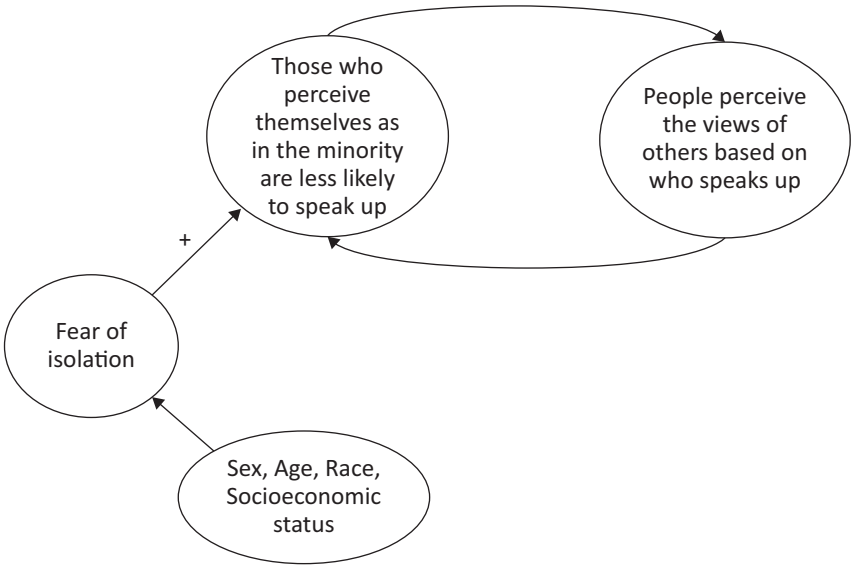

Figure 1. Representation of the spiral of silence theory as a positive feedback loop: Unless the fear of isolation is low, a group will enter a positive feedback loop, where those holding minority opinions are less and less likely to share them.

related theories of structuration are focused on how organization-level or group-level outcomes like norms, hierarchies, and meaning result from the communicative behavior of individual members (McPhee et al., 2014; Taylor & Van Every, 2000).

2.2. Systems Theory and Communication Theories

Systems theory was deeply influential for a generation of quantitative communication scholars. Despite the promise of these approaches, these early researchers suffered from two major hurdles: a lack of appropriate data and a lack of methodological tools. For many of the ideas from systems theory, data must be (a) granular, (b) longitudinal, and (c) include multiple subsystems/components. In typical work groups or firms, that makes data collection incredibly onerous and expensive.

Organizational communication researchers from this era often complained about the difficulty of collecting the necessary data to test theories about interacting systems. For example, Rogers and Agarwala-Rogers (1976) bemoaned the expense of time-series data, the difficulty of gathering longitudinal data unobtrusively, and the pressure to produce immediate results. Nearly a decade later, Monge et al. (1984) argued that organizational communication processes were well-theorized but not empirically validated in large part because of the difficulty of collecting and analyzing appropriate data.

The other major hurdle was a lack of methodological tools. These scholars had rich theories but could only approach them in fairly simple ways such as through surveys and simple regression models. Statistical tools that are valuable for studying complex systems like multilevel modeling, social network analysis, and causal inference had either not yet been developed or were in their infancy. These constraints led to empirical research that was often cross-sectional, statistically simple, and could not test for interdependent processes like feedback loops (Contractor, 1994).

The weaknesses of this first wave of systems research made studying rich or complicated questions difficult, and communication scholars began to turn to interpretive and qualitative approaches in order to explore and explain richer concepts. While many of these qualitative researchers rightly criticized the simplified, reductionist approach taken by early quantitative researchers, many of their theories either explicitly or implicitly draw on systems theory.

Perhaps the best example is CCO research. In addition to the fundamental role of the concept of emergence as explained above, CCO researchers also analyze the role of environmental contexts in which organizations are embedded (Kuhn, 2008). Indeed, CCO scholars have explicitly argued that CCO has strong overlaps with systems theory and should draw more inspiration from systems theorists (Schoeneborn, 2011). Similarly, actor–network theory is fundamentally interested in the role of relationships and interdependence (Latour, 2007). In short, while traditional systems theorists have typically taken mathematical or quantitative approaches, qualitative and interpretive communication scholars have continued to engage with and develop systems theory concepts as metaphors and conceptual frameworks.

Outside of communication, systems theory continued to develop, primarily in STEM fields (for a summary see Sawyer, 2005). In the 1990s, a number of quantitative communication scholars introduced more recent developments in systems theory—such as self-organizing systems and chaos theory—and argued for their application to communication research (Contractor, 1994; Contractor & Seibold, 1993; Poole, 1997). Many of the methodological approaches they championed were not

adopted widely, likely because the statistical, computational, and data hurdles remained. However, these researchers did help spur the adoption of social network analysis, the systems theory method which remains most common today in quantitative communication research (Monge & Contractor, 2003).

In summary, organizational communication research has been deeply influenced by systems theory but, until recently, quantitative researchers in particular have struggled to study systems theory concepts like emergence, organizational-environmental interactions, and feedback loops. The rest of this article makes an argument for the promise of applying systems approaches to online communities and identifies a nascent turn in that direction.

2.3. Online Communities

Online communities refer to groups of people that form and organize online to meet collective goals. "Online communities" is an umbrella term that encompasses both commons-based peer production (Benkler, 2006)—such as Wikipedia and open-source software where participants produce a shared output—as well as discussion-based communities—such as Reddit, where the collective goal may be information-seeking or a sense of community (Hwang & Foote, 2021; Lampe et al., 2010).

Online communities number in the millions, with many millions of participants. While it is tempting to dismiss them as simple "bulletin boards" where information is posted and shared, they are complex organizations that can perform impressive tasks. For example, collaborative projects like Wikipedia, Linux, and Firefox successfully compete with products produced by some of the most well-resourced firms in the world.

While very small online communities behave differently than large communities (Hwang & Foote, 2021), structure and organization quickly appear as they grow. Researchers have shown that even moderately large online communities and peer production projects self-organize into a small core of dedicated contributors and a large periphery of occasional participants (Crowston et al., 2006; Matei & Britt, 2017). This surprising pattern occurs everywhere we look in online communities and looks very similar across communities (Broido & Clauset, 2019). For example, Figure 2 shows the distribution of comments per member in one hundred randomly selected Reddit subreddits; while there are small differences between communities, the overall shape of the distribution—with most people contributing very few comments while a few contribute many—is identical across every subreddit.

In some ways, online communities resemble voluntary organizations (Cress et al., 1997; McPherson, 1983): As in voluntary organizations, members are typically unpaid volunteers, without formal roles, who are free to participate in multiple organizations. However, there are differences that make the success of online communities even more surprising. Contributors are producing a public information good (Fulk et al., 1996), typically having never met face-to-face and communicating only via text and the shared artifact (Bolici et al., 2016). Von Krogh and von Hippel (2006) argued that the success of online communities should cause us to question some of our assumptions about how groups and organizations work and that studying them would provide important insight not only into online communities, but into questions about motivation, self-organizing, and innovation in all types of organizations.

2.4. Online Communities as Systems

Organizational communication researchers and others have taken up this call and have worked to understand how online communities function. This work is broad and varied, including important work on how the technological features of online communities influence opportunities for collective action (Bimber et al., 2005, 2012; Fulk et al., 1996). Among many other findings, these researchers have identified three important aspects of online communities that make a systems approach vital for understanding them: (a) the role of platforms; (b) low barriers to entry, participation, and exit; and (c) fuzzy boundaries. Below I elaborate on each of these features and how they relate to systems theory.

2.4.1. The Role of Platforms

Many online communities exist on platforms, which they are only semi-independent of. Platforms often provide the technical infrastructure that an online community runs on, including software, servers, and internet connections. The goals and priorities of platforms are distinct from—and often at odds with—those of managers and members of online communities. Platforms can decide to do things like change the software, change the terms of service, or even ban online communities unilaterally; online communities have an ambivalent and complicated relationship with platforms. For example, subreddit moderators have protested platform decisions by doing things like "going dark": stopping most people from accessing or contributing to their communities (Matias, 2016).

In systems terms, platforms often act as a changing environment that an individual online community system both reacts to and influences; in other words, platform–online community dynamics are complex feedback loops. Taking this perspective helps us to identify research opportunities—for example, we might hypothesize that a platform that begins to punish controversial online communities would spur those communities to retaliate, making platforms even more likely to crack down.

2.4.2. Barriers to Entry, Participation, and Exit

Compared to offline organizations, the barriers to joining, contributing, and leaving an online group are incredibly

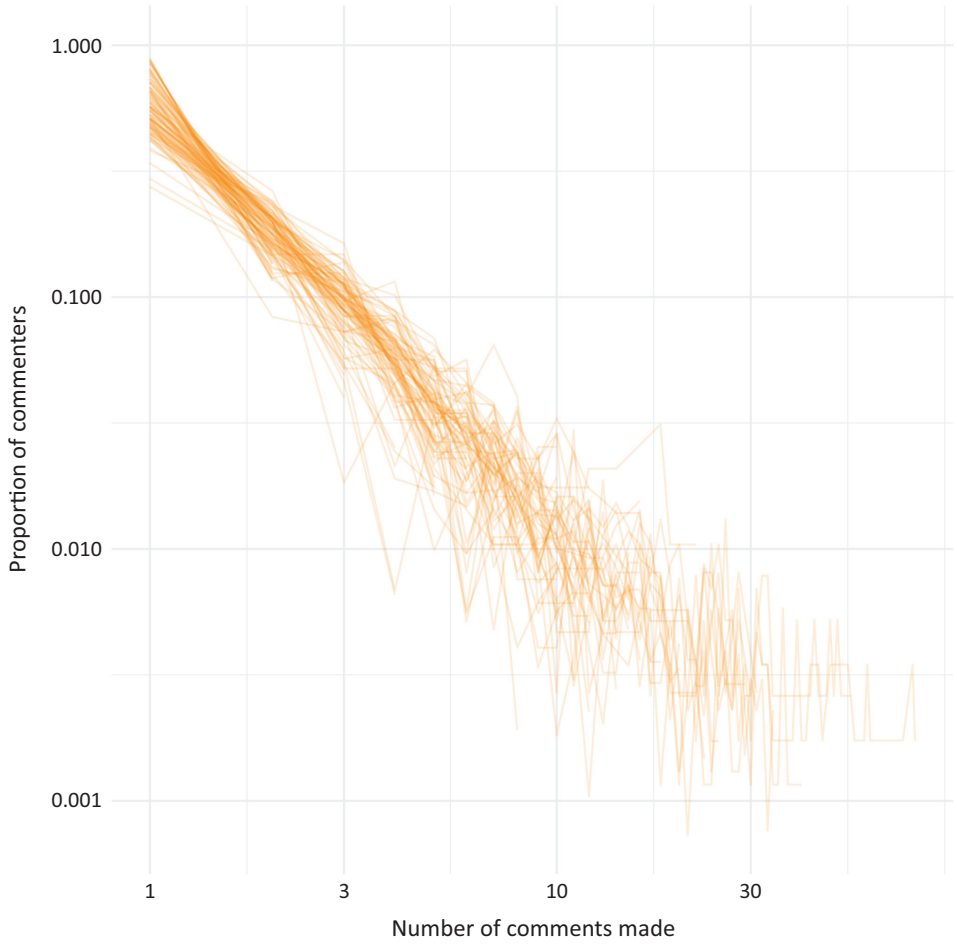

Figure 2. Distribution of comments per member across 100 randomly selected subreddits on Reddit in January 2017. Notes: The y-axis (log-scaled) shows the proportion of users making each number of comments (log-scaled); every community exhibits a very similar shape, with the lion's share of commenters only making a few comments. Before plotting, the top 5% of participants were removed in order to remove the influence of highly active bots or incredibly active users and to highlight the similarity of "typical" users across these communities.

low. Typically, the median contributor makes only a few contributions. This has a number of implications. First, communities must be constantly engaged in welcoming and onboarding newcomers, a task that gets more difficult as a group grows in size and complexity (Halfaker et al., 2013; Narayan et al., 2017). On the other hand, organizations can benefit from low cost and low effort contributions that are enabled by information technologies (Bighash et al., 2018; Bimber et al., 2005).

Unlike employees, for whom changing jobs entails significant costs, online community participants can decide minute-by-minute whether, where, and how to contribute. Typical research on these barriers might focus on understanding how to change costs to encourage participation in a given online community. A study that takes a systems approach might look at how changing participation costs influences the entire ecosystem of communities. For example, we might ask not only whether disallowing anonymous contributors decreases contributions in a focal community, as Hill and Shaw (2021) do, but also whether it drives spammers and other anonymous contributors to related communities.

2.4.3. Fuzzy Boundaries

One result of the low barriers to participation in online communities is that defining group membership is very difficult. People quickly move between communities or contribute to multiple communities nearly simultaneously. At the community level, there are also fuzzy boundaries about what to consider an online community. For example, an open-source project may consist of multiple complex modules, or a wiki may cover distinct sets of topics. As a case in point, when researchers study Wikipedia, they may identify their focal community as the entire encyclopedia (Bryant et al., 2005), a single topical "project" (Qin et al., 2015), or even a single page (Brandes et al., 2009).

Even once we draw the borders around what constitutes a given community, online communities are often intimately connected. This can be implicit—like subreddits that focus on different aspects of the same

topic (TeBlunthuis et al., in press)—or explicit—like open-source software projects that are dependencies. A systems perspective can help us to recognize that this fuzziness is not a methodological hurdle to be overcome but a key lens for understanding the dynamics of online communities. For example, we can gain insight by looking at which communities people co-contribute to and how that changes over time (Xu, 2021; Zhu et al., 2014). These fuzzy boundaries mean that the environment has an outsized role; understanding why one online community succeeds in reaching its goals while another does not usually has much more to do with how and where the organization is embedded in the larger network (i.e., system) of online communities.

In sum, online communities and the individuals within them are interconnected, interdependent organizations with fuzzy boundaries that emerge from the nearly unconstrained choices of individuals: conditions that make systems approaches vital. Systems theory can help researchers to gain new insights into how to study and theorize about the behavior and dynamics of online communities.

3. A New Opportunity

Not only is a systems theory approach especially suitable for studying online communities, but two other factors make taking a systems theory approach feasible: (a) researchers have access to immense troves of data from online community platforms and (b) computational power, methods, and interfaces have each improved to an extent that doing systems research is tractable for social scientists.

3.1. Data on Online Communities

Platforms like Reddit, GitHub, StackOverflow, and Wikipedia make an incredible wealth of data available to researchers. As part of their normal operations, these platforms track the actions that users take—such as editing pages, submitting code, or posting comments—with timestamps down to the millisecond. The opportunity provided by this "digital trace data" has been long recognized (Freelon, 2014) and communication research that uses digital trace data is increasingly common. While this data is useful for studying many communication questions, digital trace data is particularly appropriate for systems theory approaches. As explained by Rogers and Agarwala-Rogers (1976), the ideal data for systems research is longitudinal, unobtrusive, and includes many different organizations.

Indeed, data from online platforms is beyond what early researchers could even have hoped for. Often, today's researchers have access not only to what actions people take in online communities but to the full text of the communication and conversations that happen across entire platforms. These platforms consist of many different communities—sometimes thousands or hundreds of thousands—and may track millions of individual users as they interact within and move between online communities over time.

3.2. Advances in Computational Resources

In addition to ideal data for taking a systems theory lens, there have been a number of recent advances in computational resources which make this kind of work simpler to do and more valuable. The first is straightforward: computers have become much more powerful in the last few decades. Both in terms of processing power and the cost of storage and memory, modern personal computers now have the capability to run impressive, moderately large-scale analyses. This has been accompanied by advances in distributed computing such as Apache Spark, which makes analyzing even very large datasets tractable.

The second advance is in software and statistical approaches for doing large-scale and cross-community work. This includes approaches like multilevel modeling in statistics, computational text analysis tools like topic modeling and sentiment analysis (Boumans & Trilling, 2016; Jacobi et al., 2016), event-based network analysis techniques like relational event modeling and processual communication networks (Pilny et al., 2020; Schecter et al., 2018), and agent-based modeling and other simulation-based analyses (Waldherr et al., 2021), an advance discussed in more detail below.

4. Approaches

Due to these data and computational advances, quantitative organizational communication scholars have the opportunity to study the behavior of online communities and platforms as systems. The kind of systems thinking that I am proposing orients researchers to questions about things like the role of the environment, the way that systems and subsystems interact across and within different levels, and the way that feedback loops influence communities.

I believe that this type of thinking has the potential to generate exciting new research in many directions. Indeed, scholars in communication and related disciplines have already been taking advantage of the data afforded by online platforms (Lazer et al., 2009). Some of this research addresses systems theory questions. Below I describe four of the most promising approaches and give examples of recent work in communication or adjacent fields that take each approach. As an example of how generative systems thinking can be, I also provide provocations about related studies that communication researchers might consider.

4.1. Community Comparisons and Interactions

One approach enabled by rich online community data is simply to compare many online communities. One of the

weaknesses of organizational communication research is the difficulty and expense of studying even one organization in depth. Computational approaches are often very scalable—in many cases, it is nearly as easy to apply an analysis to one hundred or one thousand online communities as it is to apply it to one. One of the benefits is that large-scale comparisons allow for much stronger arguments about the generalizability of findings (Hill & Shaw, 2019). For example, Halfaker et al. (2013) identified a decline in users on English Wikipedia, positing that changes to technology and norms drove away newcomers. TeBlunthuis et al. (2018) showed that this same pattern of "rise and decline" was typical of hundreds of wikis, arguing that this pattern may be common to all online communities and calling into question the hypothesis that specific decisions made by Wikipedia were behind the drop in participation. Another benefit of studying many organizations is having the statistical power to study organization-level variables (Hill & Shaw, 2019). This allows researchers to look at things like how differences in communication structure relate to organizational outcomes (Crowston et al., 2006; Hinds & Lee, 2009; Schweik & English, 2012).

While comparing many communities can be incredibly powerful, it ignores relationships between communities. While this may be justifiable for many research questions, systems theory teaches us that for many outcomes it is important to study the way that organizations interact with each other. A growing number of communication scholars have been using a descendant of systems theory called organizational ecology to study offline organizations and online communities (Hannan & Freeman, 1977; Xu et al., 2021). The key idea of organizational ecology is that ecological relationships like competition and mutualism occur between organizations. For example, researchers have studied how topical competition influences membership (TeBlunthuis et al., 2017; Zhu et al., 2014) and how relationships between generalist and specialist social networking sites change over time (Xu, 2021).

There are exciting opportunities to extend this idea to incorporate and develop communication theories. If organizational ecology can tell us which online communities are undergoing competition, for example, then we might hypothesize that online communities undergoing intense competition would develop stronger organizational culture or identity due to the salience of other "outgroups" (Turner & Tajfel, 1986). Using a platform like GitHub, we could look for linguistic markers of group identity and examine how their prevalence changes at different levels of competition.

4.2. Individual Trajectories

The second approach treats the individual rather than the organization as the focal system. Online platform data often allows researchers to track individual users as they join, participate in, and leave communities. This data lets us study how communities influence people (and vice versa), how people decide where to participate, and which people are most likely to join or leave. Researchers studying individual trajectories have looked at things like the differences between typical Wikipedia newcomers and those who go on to become core contributors (Panciera et al., 2009) or how users adapt (or don't) to the linguistic norms of the communities they join (Danescu-Niculescu-Mizil et al., 2013). A related approach is more granular: Instead of trying to understand long-term changes to users, it uses log data to explore how one individual's actions influence others or how an individual moves through a platform in the course of a single session (e.g., Suthers, 2015).

Future research in this vein could draw more directly on both systems theory and communication theory. One key question from systems theory is how higher-level phenomena like organizations emerge from individual decisions. Individual trajectories could be used to empirically test aspects of communication theories that propose the importance of individual actions in creating or reproducing organizations. For example, researchers interested in CCO might look for ways that new community members learn about the texts of a community and how the content or patterns of their communication differs after being exposed to those texts.

4.3. Cross-Level Mechanisms

The third approach focuses on what I call cross-level mechanisms. The papers in this area look at how organization-level or platform-level decisions influence an organization or set of organizations and then look at individual-level data to understand the underlying mechanisms. For example, Nagaraj and Piezunka (2020) study how contributions to the open-source mapping system OpenStreetMap in a given country change following the entry of Google Maps as a competitor. Their initial analysis shows that competition reduces the number of contributions to OpenStreetMap. This is an important finding, but having individual-level data allows Nagaraj and Piezunka (2020) to go further, showing that this effect is driven completely by a reduction in new contributors while existing contributors actually contribute more when competition increases.

Chandrasekharan et al. (2017) take a similar approach. In their initial analysis, they show that when Reddit banned a number of toxic subreddits this did not cause an increase in the amount of hate speech used in adjacent communities. Their individual-level analysis shows that this was due both to users leaving Reddit and also because those users who stayed reduced their use of hate speech.

Communication scholars are often interested in cross-level dynamics. For example, organizational scholars might be interested in how different leaders in an online community influence both organizational-level measures of productivity or retention as well as the individual-level drivers of those measures. In order to

study these questions, a researcher could look at how adding a new moderator to a Reddit subreddit changes online community-level measures like the number of participants and could then drill down to look for things like linguistic markers of discontent.

4.4. Simulating Emergent Behavior

The fourth approach does not depend on having digital trace data at all. Communication researchers have begun to use simulation—in the form of agent-based modeling—to model how higher-level behavior can emerge from interactions. In agent-based modeling, a researcher creates a simulated society, peopled by computational "agents." Agents are simple computer programs that take in input about their environment and make decisions. Agent-based models (ABMs) are ideal for modeling system behavior because they are designed to capture feedback loops and emergence (Sawyer, 2005). While earlier software like cellular automata (Wolfram, 1984) was incredibly simple due to a lack of computational power, modern software like Mesa (Kazil et al., 2020) or NetLogo (Wilensky, 1999) makes it possible to create much more complex and realistic agents and environments.

Waldherr et al. (2021) argue that greater adoption of ABMs would benefit communication research for many reasons, including formalization, explanation, and exploration. Formalization refers to the benefits that come from explicitly encoding a theory's predictions into computer code. Waldherr et al. (2021) argue that this can help to identify ambiguities and blind spots in theories. Explanation refers to how ABMs can be used to test communication theories. Many theories make predictions about how individual-level behavior produces higher-level patterns. If agents acting according to those theories do not produce those patterns, then we know that something about the theory (or its computational representation) is wrong. Exploration refers to using ABMs for theory generation and as tools for thinking (Wilensky & Rand, 2015). AMBs can be used as digital laboratories, testing how agents behave in different contexts; interesting or surprising behavior can then be tested empirically.

Because they don't rely on large-scale data, ABMs can be used outside of the context of online communities. ABMs are an increasingly popular tool for communication scholars across interest areas. For example, a recent special issue in *Communication Methods and Measures* featured ABMs which explored how memory relates to linguistic redundancy (Oh & Kim, 2021), how group decision making can be improved by having opposing factions (Shugars, 2021), how information spreads in an information-seeking context (Reynolds, 2021), and how friendship influences and is influenced by media use (Friemel, 2021).

Many other communication theories could be explored using ABMs. To return to our spiral of silence example, researchers have used ABMs to explore questions like how the impact of the spiral of silence mechanisms differs depending on the size of a communication network (Sohn, 2019) or if manipulative bots are added to the network (Ross et al., 2019).

5. Discussion

Communication theories developed by qualitative and interpretive researchers are often about interdependent, embedded, recursive processes. The methods and conceptual advances of systems theory provide an exciting means to both test existing theories and develop new extensions. I have focused on the context of online communities as a starting point, but there is an argument to be made for the necessity and promise of taking a systems approach more broadly. While it may have made sense at one point to study only a group's offline communication patterns, contemporary communication processes now span multiple media, and the separation between online and offline and work and home are increasingly blurry. Communication research needs to consider the role of these changes, and systems thinking is vital for theorizing about our new interdependencies.

While the focus of this article has been on how new data and methods empower quantitative researchers of online communities, many of the systems-inspired research ideas that I propose above could be studied qualitatively, and qualitative researchers may also find a systems perspective generative. Indeed, understanding systems well requires combining computational and qualitative approaches, and there have been some recent methodological advances in this area. For example, Nelson (2020) introduces "computational grounded theory," an approach that goes back and forth between computational steps and interpretive steps to both gain a richer understanding of the computational output and to validate the qualitative findings.

Of course, no approach is perfect and systems theory and the approaches I have outlined have their own difficulties and drawbacks. Conceptually, one of the difficulties of systems theory is just how broad it is. By trying to abstract the concepts of interdependence across contexts, systems theory is somewhat unwieldy to try to "apply" to a given question or topic. Indeed, I have intentionally chosen a narrow set of concepts and approaches to focus on in this essay and have ignored others like chaos theory, equifinality, and autopoiesis (Poole, 2014) or cousins of systems theory like game theory, collective behavior, or evolutionary processes. I have chosen the concepts that I think are the most applicable and generative, but others would likely choose a different set of relevant concepts and approaches.

The second limitation is more practical. Many of the examples of work applying systems approaches to online communities cited above were published in computer science venues, and that is not coincidental. While there have been some noble attempts to make computational

analysis tools available to non-technical researchers (e.g., Hansen et al., 2010), in general some programming experience is required for any of the approaches discussed and the technical skill required to obtain, manage, and analyze large-scale data from online communities is still substantial.

However, there is a significant subset of this research that does not require large-scale computing resources or years of programming experience. Many programming libraries exist that make these approaches fairly straightforward. One or two semesters of programming instruction is sufficient to teach graduate students how to gather online data from APIs and conduct computational text analyses or how to create ABMs. For more complicated analyses, communication researchers can partner with computer scientists and there has been a growing movement from both fields to encourage these partnerships (Lazer et al., 2009).

6. Conclusion

We are entering a new era in organizational communication research. Online communities produce rich data at the level of individuals, organizations, and platforms. This data is already allowing us to answer new questions and gain new insight into communicative and organizing processes. Approaches like online organizational ecology, large-scale user trajectories, and agent-based modeling provide promising new avenues for developing and testing communication theories and for fulfilling the promise of systems theory that communication researchers recognized decades ago.

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Conflict of Interests

The author declares no conflict of interests.

References

Benkler, Y. (2006). *The wealth of networks: How social production transforms markets and freedom*. Yale University Press.

Bighash, L., Oh, P., Fulk, J., & Monge, P. (2018). The value of questions in organizing: Reconceptualizing contributions to online public information goods. *Communication Theory*, *28*(1), 1–21. https://doi.org/10.1111/comt.12123

Bimber, B. A., Flanagin, A. J., & Stohl, C. (2005). Reconceptualizing collective action in the contemporary media environment. *Communication Theory*, *15*(4), 365–388. https://doi.org/10.1111/j.1468-2885.2005.tb00340.x

Bimber, B. A., Flanagin, A. J., & Stohl, C. (2012). *Collective action in organizations: Interaction and engagement in an era of technological change*. Cambridge University Press.

Bolici, F., Howison, J., & Crowston, K. (2016). Stigmergic coordination in FLOSS development teams: Integrating explicit and implicit mechanisms. *Cognitive Systems Research*, *38*, 14–22. https://doi.org/10.1016/j.cogsys.2015.12.003

Boumans, J. W., & Trilling, D. (2016). Taking stock of the toolkit. *Digital Journalism*, *4*(1), 8–23. https://doi.org/10.1080/21670811.2015.1096598

Brandes, U., Kenis, P., Lerner, J., & van Raaij, D. (2009). Network analysis of collaboration structure in Wikipedia. In *Proceedings of the 18th international conference on world wide web* (pp. 731–740). Association for Computing Machinery. https://doi.org/10.1145/1526709.1526808

Broido, A. D., & Clauset, A. (2019). Scale-free networks are rare. *Nature Communications*, *10*(1), 1–10. https://doi.org/10.1038/s41467-019-08746-5

Bryant, S. L., Forte, A., & Bruckman, A. (2005). Becoming Wikipedian: Transformation of participation in a collaborative online encyclopedia. In *Proceedings of the 2005 international ACM SIGGROUP conference on supporting group work* (pp. 1–10). Association for Computing Machinery. https://doi.org/10.1145/1099203.1099205

Chandrasekharan, E., Pavalanathan, U., Srinivasan, A., Glynn, A., Eisenstein, J., & Gilbert, E. (2017). You can't stay here: The efficacy of reddit's 2015 ban examined through hate speech. In *Proceedings of the ACM on human-computer interaction* (Vol. 1, pp. 1–22). Association for Computing Machinery. https://doi.org/10.1145/3134666

Contractor, N. S. (1994). Self-organizing systems perspective in the study of organizational communication. In B. Kovacic (Ed.), *New approaches to organizational communication* (pp. 39–66). SUNY Press.

Contractor, N. S., & Seibold, D. R. (1993). Theoretical frameworks for the study of structuring processes in group decision support systems. *Human Communication Research*, *19*(4), 528–563. https://doi.org/10.1111/j.1468-2958.1993.tb00312.x

Cress, D. M., McPherson, J. M., & Rotolo, T. (1997). Competition and commitment in voluntary memberships: The paradox of persistence and participation. *Sociological Perspectives*, *40*(1), 61–79. https://doi.org/10.2307/1389493

Crowston, K., Wei, K., Li, Q., & Howison, J. (2006). Core and periphery in free/libre and open source software team communications. In *Proceedings of the 39th annual Hawaii international conference on sys-*

tem sciences (pp. 118a-118a). IEEE. https://doi.org/10.1109/HICSS.2006.101

Danescu-Niculescu-Mizil, C., West, R., Jurafsky, D., Leskovec, J., & Potts, C. (2013). No country for old members: User lifecycle and linguistic change in online communities. In Proceedings *of the 22nd international conference on world wide web* (pp. 307–318). Association for Computing Machinery. https://doi.org/10.1145/2488388.2488416

DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional Isomorphism and collective rationality in organizational fields. *American Sociological Review*, *48*(2), 147–160. https://doi.org/10.2307/2095101

Farace, R. V., Monge, P. R., & Russell, H. M. (1977). *Communicating and organizing*. Random House.

Freelon, D. (2014). On the interpretation of digital trace data in communication and social computing research. *Journal of Broadcasting & Electronic Media*, *58*(1), 59–75. https://doi.org/10.1080/08838151.2013.875018

Friemel, T. N. (2021). Co-orientation of media use: Studying selection and influence processes in social networks to link micro behavior of TV and YouTube use to meso-level structures. *Communication Methods and Measures*, *15*(4), 312–331. https://doi.org/10.1080/19312458.2020.1745766

Fulk, J., Flanagin, A. J., Kalman, M. E., Monge, P. R., & Ryan, T. (1996). Connective and communal public goods in interactive communication systems. *Communication Theory*, *6*(1), 60–87. https://doi.org/10.1111/j.1468-2885.1996.tb00120.x

Halfaker, A., Geiger, R. S., Morgan, J. T., & Riedl, J. (2013). The rise and decline of an open collaboration system: How Wikipedia's reaction to popularity is causing its decline. *American Behavioral Scientist*, *57*(5), 664–688. https://doi.org/10.1177/0002764212469365

Hannan, M. T., & Freeman, J. (1977). The population ecology of organizations. *American Journal of Sociology*, *82*(5), 929–964. https://doi.org/10.2307/2777807

Hansen, D., Shneiderman, B., & Smith, M. A. (2010). *Analyzing social media networks with NodeXL: Insights from a connected world*. Morgan Kaufmann.

Hill, B. M., & Shaw, A. (2019). Studying populations of online communities. In B. Foucault Welles & S. González-Bailón (Eds.), *The Oxford handbook of networked communication* (pp. 173–193). Oxford University Press.

Hill, B. M., & Shaw, A. (2021). The hidden costs of requiring accounts: Quasi-experimental evidence from peer production. *Communication Research*, *48*(6), 771–795. https://doi.org/10.1177/0093650220910345

Hinds, D., & Lee, R. M. (2009). Communication network characteristics of open source communities. *International Journal of Open Source Software and Processes*, *1*(4), 26–48. https://doi.org/10.4018/jossp.2009100102

Hwang, S., & Foote, J. D. (2021). Why do people participate in small online communities? *Proceedings of the ACM on Human-Computer Interaction*, *5*(CSCW2), Article 462. https://doi.org/10.1145/3479606

Jacobi, C., van Atteveldt, W., & Welbers, K. (2016). Quantitative analysis of large amounts of journalistic texts using topic modelling. *Digital Journalism*, *4*(1), 89–106. https://doi.org/10.1080/21670811.2015.1093271

Katz, D., & Kahn, R. L. (1966). *The social psychology of organizations*. Wiley & Sons.

Kazil, J., Masad, D., & Crooks, A. (2020). Utilizing python for agent-based modeling: The mesa framework. In R. Thomson, H. Bisgin, C. Dancy, A. Hyder, & M. Hussain (Eds.), *Social, cultural, and behavioral modeling* (pp. 308–317). Springer.

Kuhn, T. (2008). A communicative theory of the firm: Developing an alternative perspective on intra-organizational power and stakeholder relationships. *Organization Studies*, 29(8-9), 1227–1254. https://doi.org/10.1177/0170840608094778

Lai, C.-H., & Lin, S. H. (2017). Systems theory. In C. R. Scott, J. R. Barker, T. Kuhn, J. Keyton, P. K. Turner, & L. K. Lewis (Eds.), *The international encyclopedia of organizational communication* (pp. 1–18). Wiley. https://doi.org/10.1002/9781118955567.wbieoc203

Lammers, J. C., & Barbour, J. B. (2006). An institutional theory of organizational communication. *Communication Theory*, *16*(3), 356–377. https://doi.org/10.1111/j.1468-2885.2006.00274.x

Lampe, C., Wash, R., Velasquez, A., & Ozkaya, E. (2010). Motivations to participate in online communities. In *Proceedings of the 28th international conference on human factors in computing systems* (pp. 1927–1936). Association for Computing Machinery. https://doi.org/10.1145/1753326.1753616

Latour, B. (2007). *Reassembling the social: An introduction to actor-network-theory*. Oxford Univ. Press.

Lazer, D., Pentland, A., Adamic, L., Aral, S., Barabasi, A. L., Brewer, D., Christakis, N., Contractor, N. S., Fowler, J., Gutmann, M., Jebara, T., King, G., Macy, M., Roy, D., & Van Alstyne, M. (2009). Life in the network: The coming age of computational social science. *Science*, *323*(5915), 721–723. https://doi.org/10.1126/science.1167742

Matei, S. A., & Britt, B. C. (2017). *Structural differentiation in social media: Adhocracy, entropy, and the "1% effect."* Springer.

Matias, J. N. (2016). Going dark: Social factors in collective action against platform operators in the Reddit blackout. In *Proceedings of the 2016 CHI conference on human factors in computing systems* (pp. 1138–1151). Association for Computing Machinery. https://doi.org/10.1145/2858036.2858391

McPhee, R. D., Poole, M. S., & Iverson, J. (2014). Structuration theory. In L. L. Putnam & D. K. Mumby

(Eds.), *The SAGE handbook of organizational communication: Advances in theory, research, and methods* (Vol. 3, pp. 1–15). SAGE.

McPherson, J. M. (1983). An ecology of affiliation. *American Sociological Review*, *48*(4), 519–532. https://doi.org/10.2307/2117719

Monge, P. R., & Contractor, N. S. (2003). *Theories of communication networks*. Oxford University Press.

Monge, P. R., Farace, R. V., Eisenberg, E. M., Miller, K. I., & White, L. L. (1984). The process of studying process in organizational communication. *Journal of Communication*, *34*(1), 22–43.

Nagaraj, A., & Piezunka, H. (2020). *How competition affects contributions to open source platforms: Evidence from OpenStreetMap and Google Maps* (Working Paper). https://abhishekn.com/files/openstreetmap_google_feb2020.pdf

Narayan, S., Orlowitz, J., Morgan, J., Hill, B. M., & Shaw, A. (2017). The Wikipedia adventure: Field evaluation of an interactive tutorial for new users. In *Proceedings of the 2017 ACM conference on computer supported cooperative work and social computing* (pp. 1785–1799). Association for Computing Machinery. https://doi.org/10.1145/2998181.2998307

Nelson, L. K. (2020). Computational grounded theory: A methodological framework. *Sociological Methods & Research*, *49*(1), 3–42. https://doi.org/10.1177/0049124117729703

Noelle-Neumann, E. (1974). The spiral of silence: A theory of public opinion. *Journal of Communication*, *24*(2), 43–51. https://doi.org/10.1111/j.1460-2466.1974.tb00367.x

Oh, P., & Kim, S. (2021). An evolutionary model of the emergence of meanings. *Communication Methods and Measures*, *15*(4), 255–272. https://doi.org/10.1080/19312458.2020.1768519

Panciera, K., Halfaker, A., & Terveen, L. (2009). Wikipedians are born, not made: A study of power editors on Wikipedia. In *Proceedings of the ACM 2009 international conference on supporting group work* (pp. 51–60). Association for Computing Machinery. https://doi.org/10.1145/1531674.1531682

Pilny, A., Dobosh, M., Yahja, A., Poole, M. S., Campbell, A., Ruge-Jones, L., & Proulx, J. (2020). Team coordination in uncertain environments: The role of processual communication networks. *Human Communication Research*, *46*(4), 385–411. https://doi.org/10.1093/hcr/hqz020

Poole, M. S. (1997). A turn of the wheel: The case for renewal of systems inquiry in organizational communication research. *Organization Communication: Emerging Perspectives*, *5*, 47–63.

Poole, M. S. (2014). Systems theory. In L. Putnam & D. Mumby (Eds.), *The SAGE handbook of organizational communication: Advances in theory, research, and methods* (pp. 49–74). SAGE.

Qin, X., Cunningham, P., & Salter-Townshend, M. (2015). The influence of network structures of Wikipedia discussion pages on the efficiency of WikiProjects. *Social Networks*, *43*, 1–15. https://doi.org/10.1016/j.socnet.2015.04.002

Reynolds, R. M. (2021). Diffusion in information-seeking networks: Testing the interaction of network hierarchy and fluidity with agent-based modeling. *Communication Methods and Measures*, *15*(4), 292–311. https://doi.org/10.1080/19312458.2020.1784401

Rogers, E. M., & Agarwala-Rogers, R. (1976). *Communication in organizations*. The Free Press.

Ross, B., Pilz, L., Cabrera, B., Brachten, F., Neubaum, G., & Stieglitz, S. (2019). Are social bots a real threat? An agent-based model of the spiral of silence to analyse the impact of manipulative actors in social networks. *European Journal of Information Systems*, *28*(4), 394–412. https://doi.org/10.1080/0960085X.2018.1560920

Sawyer, R. K. (2005). *Social emergence: Societies as complex systems*. Cambridge University Press.

Schecter, A., Pilny, A., Leung, A., Poole, M. S., & Contractor, N. (2018). Step by step: Capturing the dynamics of work team process through relational event sequences. *Journal of Organizational Behavior*, *39*(9), 1163–1181. https://doi.org/10.1002/job.2247

Schoeneborn, D. (2011). Organization as communication: A luhmannian perspective. *Management Communication Quarterly*, *25*(4), 663–689. https://doi.org/10.1177/0893318911405622

Schweik, C. M., & English, R. C. (2012). *Internet success: A study of open-source software commons*. MIT Press.

Shugars, S. (2021). Good decisions or bad outcomes? A model for group deliberation on value-laden topics. *Communication Methods and Measures*, *15*(4), 273–291. https://doi.org/10.1080/19312458.2020.1768521

Sohn, D. (2019). Spiral of silence in the social media era: A simulation approach to the interplay between social networks and mass media. *Communication Research*, *49*(1). https://doi.org/10.1177/0093650219856510

Suthers, D. (2015). From contingencies to network-level phenomena: Multilevel analysis of activity and actors in heterogeneous networked learning environments. In *Proceedings of the fifth international conference on learning analytics and knowledge* (pp. 368–377). Association for Computing Machinery. https://doi.org/10.1145/2723576.2723626

Taylor, J. R., & Van Every, E. J. (2000). *The emergent organization: Communication as its site and surface*. Lawrence Erlbaum Associates.

TeBlunthuis, N., Kiene, C., Brown, I., Levi, L., McGinnis, N., & Hill, B. M. (in press). No Community Can Do Everything: Why People Participate in Similar Online Communities. *Proceedings of the ACM on Human-Computer Interaction*.

TeBlunthuis, N., Shaw, A., & Hill, B. M. (2017). Density dependence without resource partitioning: Popula-

tion ecology on Change.org. In *Companion of the 2017 ACM conference on computer supported cooperative work and social computing* (pp. 323–326). Association for Computing Machinery. https://doi.org/10.1145/3022198.3026358

TeBlunthuis, N., Shaw, A., & Hill, B. M. (2018). Revisiting "The rise and decline" in a population of peer production projects. In *Proceedings of the 2018 CHI conference on human factors in computing systems* (pp. 1–7). Association for Computing Machinery. https://doi.org/10.1145/3173574.3173929

Turner, J. C., & Tajfel, H. (1986). The social identity theory of intergroup behavior. *Psychology of Intergroup Relations*, *5*, 7–24.

von Krogh, G., & von Hippel, E. (2006). The promise of research on open source software. *Management Science*, *52*(7), 975–983. https://doi.org/10.1287/mnsc.1060.0560

Waldherr, A., Hilbert, M., & González-Bailón, S. (2021). Worlds of agents: Prospects of agent-based modeling for communication research. *Communication Methods and Measures*, *15*(4). https://doi.org/10.1080/19312458.2021.1986478

Wiener, N. (1948). Cybernetics. *Scientific American*, *179*(5), 14–19.

Wilensky, U. (1999). *NetLogo*. Center for Connected Learning and Computer-Based Modeling, Northwestern University.

Wilensky, U., & Rand, W. (2015). *An introduction to agent-based modeling: Modeling natural, social, and engineered complex systems with NetLogo*. MIT Press.

Wolfram, S. (1984). Cellular automata as models of complexity. *Nature*, *311*(5985), 419–424. https://doi.org/10.1038/311419a0

Xu, Y. (2021). Evolution of audience duplication networks among social networking sites: Exploring the influences of preferential attachment, audience size, and niche width. *New Media & Society*. Advance online publication. https://doi.org/10.1177/14614448219933048

Xu, Y., Hazée, S., So, K. K. F., Li, K. D., & Malthouse, E. C. (2021). An evolutionary perspective on the dynamics of service platform ecosystems for the sharing economy. *Journal of Business Research*, *135*, 127–136. https://doi.org/10.1016/j.jbusres.2021.05.056

Zhu, H., Kraut, R. E., & Kittur, A. (2014). The impact of membership overlap on the survival of online communities. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 281–290). Association for Computing Machinery. https://doi.org/10.1145/2556288.2557213

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