Connecting Online and Offline Worlds: The Impact of Cross-Boundary Artifact on Hybrid Communities

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Hybrid online-offline communities, known as online socio-technical platforms with explicit goals to facilitate offline interactions are thriving and more than ever obscuring the borders between physical and digital communities. However, members of these communities often face information asymmetry. Quality and information about the offline gatherings is visible to members who physically attend offline activities, but often not to those who did not attend the gatherings. Offline information such as the events' whereabouts and the groups' social dynamics can be essential to make the decision of attending a future event. In this dissertation, I studied the challenges and opportunities to utilize cross-boundary artifacts, defined as objects which capture offline activities and can be shared in the online space, to reduce information asymmetry in hybrid communities. I conducted three studies including an interview study, an online survey, and a controlled lab experiment. The result of my interview reveals organizers most importantly judge the success of their event based on the offline experiences. They acknowledged the potential benefits of sharing offline experiences back to the online space (i.e. setting expectations, building community images), but also expressed concerns about the lack of support in current systems in representing offline interactions. The online survey and the controlled lab experiment examined what roles cross-boundary artifacts can play in reducing information asymmetry and how they can be better incorporated and represented in the current systems. The results show that such artifacts embed rich and reliable signals and they convey valuable information about what happened in the offline activities. Their impact on offline participation varies by the format and volume of artifacts and the goals of target participants. My dissertation presents the first piece of research on hybrid communities focusing on the mechanisms and artifacts to connect online and offline spaces. This work also provides guidelines to designers, developers and practitioners of social technologies seeking to study or design technologies for hybrid communities.

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1.0   Introduction

Internet has been greatly embedded in the modern society and everyday life of many individuals. Its rapid development in the last thirty years has undoubtedly changed the way in which people interact with each other. Internet allows individuals to easily connect and interact with others in the virtual world no matter how far they are from each others in the physical world.

Recent years have witnessed the rise of an emerging model of computer-mediated communication spanning online and offline worlds. As an example, the fever of Pokémon GO in 2016 unfolded the potentials in bridging online and offline worlds by adopting information technology[22]. According to the 2013 report of Center for the Digital Future, 48% of online community participants meet other members offline [1]. Online platforms with explicit goals of promoting offline connections and facilitating in-person gatherings of individuals have been thriving. Meetup[1], Airbnb[2], and NextDoor[3] are a few examples of such platforms. This emerging mixed online-offline model of interaction gave birth to what is known as **hybrid communities** [67]. The term "hybrid communities" often refers to "physical spaces intertwined with digital communities" [39, 45, 23]; however, a clear and consistent definition of hybrid communities is still missing. According to prior research [44], a digital or virtual community "consists of people who interact together socially on a technical platform. The community is built on a common interest, a common problem, or a common task of its members that is pursued on the basis of implicit and explicit codes of behaviour. The technical platform enables and supports the community's interaction." Building on this, Gaved et al. [28] suggested that **a hybrid community can be defined as "a community consisting of people who interact together socially using both online and offline methods of communication."** That is, a hybrid community enables two forms of interactions: online interactions through computer-mediated communications and face-to-face interactions through in-person offline gatherings [79]. Hybrid communities benefit from both technolog-

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[1]https://www.meetup.com/
[2]https://airbnb.com/
[3]https://nextdoor.com/

ical features and in-person connections. Technology helps, for example, to find like-minded people among a large number of people while offline interactions allow people to become more familiar and connected with a smaller group of people.

1.1 Problem Statement

1.1.1 Defining hybrid communities in this work

While the mixed online-offline interaction model is the basis of hybrid communities, the proportion of online and offline channels used to communicate often varies for different kinds of hybrid communities. For example, a hybrid community such as an online gaming group may primarily interact in the online platform while occasionally host in-person meetups. On the other hand, a neighborhood community may often host regular offline meetings or organize local activities but use an online group as the secondary channel to share announcements and facilitate communications among neighbors. Further, hybrid communities can be classified according to a variety of dimensions. As listed in Table 1, I summarized four key dimensions that help to provide an overview of different types of hybrid communities, including (1) the main entry point of members to the community; (2) the role of offline interactions; (3) the primary type of local connections the community aims to build; (4) the leadership style (i.e. whether designated leaders are essential to the community). These four dimensions provide a mean to classify any hybrid communities into particular categories. Examples of the classification are listed in Table 2.

In the scope of this dissertation, I focus on hybrid communities with offline interactions as the essential channel of communication. That is, members in such communities cannot achieve their goals without participating in offline activities, such as members in Meetup groups or student clubs. In particular, I decided to use communities like Meetup groups as my research model since most people joined Meetup groups from the online space. Compared to student clubs, Meetup groups rely more on the online space to support individuals looking for others with common interests and goals in their local area [77]. Without the opportu-

nities to learn about the community in the offline space, I argue that those communities face more challenges to recruit and retain members. Hence, my dissertation aims to understand opportunities to support such hybrid communities by bridging the online and offline spaces. **In the rest of this dissertation, unless otherwise stated, the term "hybrid communities" is referred to communities consisting of people who interact using both online and offline communication channels; further, members mostly join the community from the online channels while offline interactions are essential for members to achieve their goals.**

1.1.2 Information asymmetry in hybrid communities

The hybrid online-offline nature of the emerging model has shown to contribute to significant positive outcomes such as community development [31], citizen engagement in political and social movements [32, 77] as well as empowering individuals to develop and transform their social identities in relation to temporal and spatial connections to their residence and others co-residing their locale [28, 39, 33]. However, we still have very little knowledge about how to engage participation in hybrid communities over time.

The issue of community building and member engagement in either online communities or offline organizations is not a new topic. Prior researchers in CSCW and organizational studies have made a lot of effort on exploring strategies to build successful communities and to engage long-term participation [41]. However, this issue becomes more complex due to the mixed online and offline nature of interaction patterns in hybrid communities. Members of these communities often face *information asymmetry*. Quality and information about the offline gatherings is visible to members who physically attend offline activities, but often not to those who did not attend the gatherings [21]. Similarly, the online interactions are not situated within the offline gatherings and are disconnected from the face-to-face interactions.

For a new member or an existing member exploring a new group or a new activity, information about prior events can be essential in making the decision to attend an upcoming event. According to *uncertainty reduction theory*, reducing uncertainty and increasing predictability about the behavior of others play a critical role in increasing comfort with meeting

Table 1: Four dimensions to classify hybrid communities

Dimension	Description	Categories
Entry Point	The place where individuals interact at the first time in the community	• Mostly online space • Mostly offline space
Role of offline interactions	The function of offline interactions to the expected outcomes of the community	• Essential: Individuals can not achieve their main goal without interacting with others offline • Secondary: Offline interactions are supported in the community but it is not indispensable for individuals to achieve their goals
Primary type of local connections to build	What is the primary type of connections the community aims to build with regards to the physical world?	• Connections between people and local resources • Connections among people within a geographic boundary • Both
Leadership style	Are designated leaders essential or optional in the community?	• Essential • Optional

Table 2: Examples of classified hybrid communities

Dimension	Meetup groups	Student clubs in high schools	Hyper-local News Communities	Foursquare
Entry Point	Mostly online	Mostly offline	Mostly online	Mostly online
Role of offline interactions	Essential	Essential	Secondary	Secondary
Primary type of connections to build	Connections among people within a geographic boundary	Connections among people within a geographic boundary	Both	Connections between people and local resources
Leadership style	Essential	Essential	Optional	Optional

new people [7]. To reduce uncertainty, people pursue active strategies; most importantly they often actively engage in seeking information to increase their knowledge about people and situation they will encounter [47, 5, 72]. In the context of hybrid communities, members make decisions about in-person meetings based on information provided in the online platform [52]. However, these is often very limited information beyond the formal description of events in the online platform. An individual can be interested in understanding how busy an event gets, how interactive, enjoyable, or fun the event is, or what demographics of people attend the event. Some of this information is available on platforms such as Meetup.com; however, often not very visible. Other information such as experiences of attendees during the event is hardly ever reflected online. This is a case of decision making process in face of *information asymmetry* [76]; i.e. different people have different information and those who have to make the decision do not have the information that others might have which can support their decision making process [16]. In face of lack of direct information, as explained by *signaling theory*, we rely on signals to assess the quality of the situation. Signals are "indicators of otherwise hidden qualities" [16, 18].

In fact, the awareness of past activities in the community has been found as a critical factor to stimulate members' participation in online communities [10, 60, 43]. Further, my

previous study showed that the online representation of offline activities increased by photos and comments shared in hybrid communities are significantly associated with the level of members' future participation [21]. Similarly, prior research also suggested that artifacts such as photos or videos shared and displayed in the physical space can increase social awareness among a distributed group of people [19]. Therefore, I argue that artifacts which can travel between online and offline worlds help to reduce information asymmetry in hybrid communities and therefore support future participation.

In my dissertation, I focus on these *cross-boundary artifacts* and investigate their impact on hybrid communities. In particular, I define *cross-boundary artifacts* in the context of hybrid communities as objects which capture offline activities and can be shared in the online space. Examples of such artifacts include text-based items (e.g. comments/blog entries/reports about offline events) and visual objects such as photos or videos capturing offline activities. While prior research seems to indicate the promising role of cross-boundary artifacts to increase awareness of offline activities in hybrid communities, it remains unclear that what information can be carried by such artifacts and what is their capacity to communicate signals about offline activities and further stimulate participation.

While the primary focus of this dissertation is to investigate the role and impact of cross-boundary artifacts on hybrid communities, I realized that we need to take one step back and asked ourselves a question: do we have a comprehensive understanding of the context of hybrid communities yet? Unfortunately, the answer is "no". In order to identify the potential opportunities to design and utilize cross-boundary artifacts to connect online and offline worlds, we need to first answer a set of fundamental questions: Why is it important to connect the two spaces in hybrid communities? What is the motivations and goals of building hybrid communities? How do the interactions in online and offline worlds relate to the success of hybrid communities? All of those questions would help to suggest how we should design cross-boundary artifacts to fulfill and facilitate members' need in a such unique context.

1.2 Dissertation Work

The primary goal of my dissertation is to understand how *cross-boundary artifacts* can be designed and used to bridge online and offline spaces in hybrid communities. In particular, how they can be utilized to reduce information asymmetry and facilitate offline participation. I conducted a mixed-method empirical investigation with three studies focusing on the role and impact of cross-boundary artifacts. In the following sections, I will summarize the research goals, methods and results of each study respectively.

Importance of connecting online and offline spaces. While we observed that in hybrid communities, people's footprints in the offline world are often absent in the offline space, there is still a fundamental question that remains unclear - why do we care about transferring offline footprints back to the online space? That is, is it important to connecting online and offline space in hybrid communities? To answer this question, I conducted interviews with twelve event organizers on an exemplary platform of hybrid communities (Meetup.com). Our goal of *Study 1* is to understand the context of hybrid communities and identify the opportunities and challenges to bridge online and offline spaces. The results of *Study 1* reveal that offline interaction is the core of hybrid communities as people are motivated by the opportunities to interact and contribute within the local space and also evaluate the success based on the quality of their offline experience. Further, organizers acknowledged the potential benefits of sharing offline experiences in the online space such as setting expectations for future participation, collecting feedback from attendees, and building profile for the group. However, organizers also expressed their uncertainty about the best practices to share offline experiences. Some of them have tried to use cross-boundary artifacts, especially visual artifacts like pictures; but, they are also concerned about the capacity of those artifacts in representing offline interactions among attendees and their direct influence on offline participation.

Capacity of Cross-boundary Artifacts. In order to assess the capacity of visual cross-boundary artifacts, *Study 2* was designed to systematically examine which signals can be communicated through event pictures, what kind of information such signals can convey, and how reliable these signals are to support users' assessment of the quality of an

event. I conducted an online study to present a collection of photos associated with a set of Meetup events and assess what information users can infer about the events from each photo collection. The results of Study 2 showed that pictures embed rich and reliable signals that can be intuitively and accurately interpreted, and they convey valuable information about what happened in the offline activities. The large majority of our respondents were able to infer information about "what the event is about and whereabouts of the event", "social dynamics of the event", "how many people and what kind of people attended the event", "how the event went". The findings of this study informed the opportunities to utilize event pictures to convey reliable signals about offline happenings back to the online platform to assist those who did not attend the event in better understanding of offline events.

Impact of Cross-boundary Artifacts on Decision Making Process. To further explore whether the information of offline activities carried by cross-boundary artifacts can influence people's decision-making process of participating offline, I designed a controlled lab experiment (*Study 3*). The objective of this study is to examine how the three key characteristics of cross-boundary artifacts, including *Format*, *Quantity* and *Signal strength of offline interactions*, impact people's decision making process. Our results showed that cross-boundary artifacts conveying signals about previous events in the group are effective to reduce people's uncertainty about upcoming events. While the format of cross-boundary artifacts does not significantly impact the effect of such artifacts, we need to consider design-ing visual and textual artifacts differently, with respect to the quantity of artifacts and goals of target participants, in order to to maximize their impact on supporting decision making. The results of this study demonstrated the opportunities to design and utilize cross-boundary artifacts to help members without prior experience of offline activities to make decisions of attending future events.

1.3   Organization of this dissertation

This dissertation is structured as follows. Chapter 2 summarized the related work about hybrid communities and the problem that motivates my dissertation. Chapter 3 introduces

a brief description of the research platform in my dissertation: Meetup.com. Chapters 4, 5 and 6 describe the three studies that were conducted as part of my dissertation work. Chapter 4 reports on an exploratory analysis of hybrid communities with respect to its unique online-offline interaction model. This chapter summarizes the results of an interview study and describes the motivations, expectation and experience of members who often organized offline events in hybrid communities. Chapter 5 presents an online survey study to investigate the role visual cross-boundary artifacts on conveying signals of offline activities. Chapter 6 further shows the impact of cross-boundary artifacts on supporting the members in the community to make decisions about participating in future offline activities by reporting results of a controlled lab experiment. Chapter 7 discusses the results of the three studies in conjunction and their implications. Finally, Chapter 8 concludes this doctoral dissertation by summarizing its contributions.

2.0 Related Work

Several research area can inform my investigation of the role of cross-boundary artifacts in the context of hybrid communities. In this chapter, I will introduce the three major strands of research that congregate most of the literature that frame my dissertation work. First, I summarized the existing research of hybrid communities, focusing on the mixed online and offline interactions model in such socio-technical systems. Second, I presented a review of literature about signaling theory in eliminating the problem of information asymmetry in both online and offline worlds. Last, I introduced a set of prior study on photo sharing in online social systems which informs how the content of photo shared and the sharing practice can influence the social interactions and communication process.

2.1 Hybrid communities

While the concept of "hybrid communities" has only been introduced for less than a decade, the hybrid online-offline interaction model has been discussed earlier in the field of online communities. Many online communities have attempted to utilize face-to-face communications or offline gatherings to supplement online interactions among users, even when they were designed for mainly supporting online interactions among geographically distributed individuals [65, 70, 74, 58, 46]. According to the 2013 report of Center for the Digital Future, 48% of online community participants said they meet other members offline [1]. Park and Floyd found that there is often no clear line between online and offline activities for members in online newsgroups while they attempt to build social relationships. They showed that a large number of individuals supplement the online interaction through other mediums such as phone calls, and face-to-face interactions and about 33% of interpersonal connections built in the online space would migrate to offline context [65]. It has been suggested that offline communications can foster computer-mediated social relationships [56] and individuals' sense of belonging in online communities [46]. For example, Rothaermel and Sugiyama [71]

argued for offline communication as a significant factor in explaining embedding of members in an online community, and therefore strengthening the relationship-building process among members. The results of a survey study of 172 users in 44 online communities also revealed that offline interactions promote the solidarity and cohesiveness of an online community, and strengthen the links between members [40]. Further, Lin [46] showed that the offline activities are important determinants of success of online communities since they significantly affect the sense of belonging. Moreover, offline interactions can influence the contribution behavior and collaboration pattern of members in online communities [58]. By conducting both interviews and content analysis of users' online and offline activities in an online community, McCully et al. showed that attending offline activities can foster members' subsequent contribution, facilitate collaboration through increased awareness of community members and promote the sense of belonging to the community. In particular, they found that offline meetings help to not only extending online encounters into richer relationships by deepening interactions with offline social signals, but also the socialization of newcomers into the community. In terms of long term effect, Angelopoulos and Merali [3] conducted a longitudinal study of an online community of cigar smokers, and demonstrated that offline interactions play a significant role for social networking which increase the number of threads, posts and private messages in the online forum.

While there is strong evidence in support of supplementing online interactions with offline gatherings, there is also evidence that highlights the challenges arising as a result of offline connections. In some cases, offline connections can lead to weakening of the online interactions as a result of creating stronger clicks among those who can meet offline, or by shifting the interactions offline thereby reducing online interactions [73]. It has been argued that offline gatherings can promote stronger bonds that lead to stronger bonding social capital, but this is accomplished at the expense of decreasing weak ties and bridging social capital [74]. Overall, the studies exploring impact of offline gatherings are scarce and this particular area of research has remained relatively unexplored as compared to other aspects of online communities research [36].

The intertwined online-offline nature attracted more attention in the research community when the concept of hybrid communities was first introduced in 2003 [67] and defined as

"physical spaces intertwined with digital communities" [39, 45, 23]. In fact, there were two trends of research utilize the concept of "hybrid communities" in two different contexts. One line of research use "hybrid communities" to describe "a physical community extended by a network infrastructure, seeking to enhance existing social interactions, storage and dissemination of knowledge using both online and offline channels of communication" [27]. Typical examples of this type of hybrid communities include neighborhood discussion forums (e.g. E-democracy[1]), neighborhood social networking sites (e.g. Nextdoor[2]), and intranet social networking sites within enterprises (e.g. IBM connections). This type of hybrid communities encourage online and offline interactions among members by facilitating and strengthen the connections already formed offline and in-person with online support. In contrast, another line of research introduced "hybrid communities" as socio-technical systems that aims to facilitate face-to-face connections among strangers by providing an online space to support individuals looking for others with common interests and goals in their local communities [26, 77]. As an example, an event-based social network such as Meetup groups allows its members to find others with similar interests and to organize themselves to get together as a group or "meet up" offline [77].

The key distinctive characteristic between those two types of hybrid communities is whether or not the offline interactions are essential to fulfill members' needs in the community and further determine the success of communities. The former type of hybrid communities are often founded by or highly associated with an existing offline organization such as a neighborhood community or an enterprise and online systems are often used as secondary offline communication channels to supplement the needs of members. Researchers have found that the offline organizational structures and characteristics play an important role on the success of such communities [51]. Conversely, the latter type of hybrid communities are mainly formed without prior offline connections and members are often mind-liked strangers in real world. How to maintain such communities to success over time without a structured offline organization becomes a vital challenge for both researchers, technology designers and community practitioners. Most importantly, the connection of online and offline space is

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[1]http://forums.e-democracy.org/
[2]https://nextdoor.com/

more critical in the second type of hybrid communities. The offline interactions would not be possible if the online community does not enable the communications among people. However, there has been in fact less attention paid to the second type of hybrid communities in the research community. Thus, in this dissertation, I focus on the latter type of hybrid communities and aim to tackle the challenges of making these communities successful.

With respect to the hybrid online-offline interaction nature, researchers claimed that sustaining both thriving online and offline interactions is vital for the health of hybrid communities [36, 70]. Online interactions provide capabilities of communications between distributed members as well as allowing access to electronically stored resources, while face-to-face interaction has its own strength of providing nonverbal cues that compensate for a recognized deficiency in computer-mediated communications [36].

However, researchers also concerned that supporting members to fluidly travel between and participate in both these two spaces are challenging. In particular, the awareness about and the impact of the interplay between online and offline interactions have often been overlooked. While online connections and interactions are quite visible, online-offline connections are usually latent to members of hybrid communities. What happens offline is often invisible in the online space. Using Meetup groups as examples, my previous collaborative work showed that presenting prior offline activities through photos in the online platform is an effective mechanism to facilitate future participation in hybrid communities [21]. This finding is also confirmed by a recent study of Social Street groups on Facebook [61]. Social Street initiatives aim to combines online interactions in a closed Facebook group with face-to-face meetings seeking to practically engage the collective in accomplishing certain immediate or ongoing needs within local neighborhoods. By conducting a two-year ethnographic study, researchers found reporting the activities and artifacts created in the offline meetings back to the online group enables ongoing scope for participation amongst currently less active members in future interventions. In my dissertation, I further investigate the impact of the content and sharing of cross-boundary artifacts on success of hybrid communities. Considering the efforts people need to invest and the popularity of uses, this dissertation focuses on comments and photos as exemplary types of cross-boundary artifacts to study the role of them in hybrid communities.

2.2 Information asymmetry and signaling theory

Signaling theory helps to explain the behavior of two parties when the problem of information asymmetry exists; i.e. different people have different information and people need to assess the quality of the situation with limited information [16]. Strategic signaling refers to actions taken by a signaler to influence views and behaviors of receivers [57]. Typically, the signaler chooses whether and how to communicate (or signal) certain information, and the other party, the receiver, then choose how to interpret the signal. While the signalers may obtain both positive and negative information of a situation or product, signalling theory focuses primarily on the deliberate communication of positive information in an effort to convey positive attributes towards a brand or product. For instance, product advertisements often aim to communicate positive signals to inform good product quality so that consumers are more willing to trust the brand and make purchases. Signaling theory has been widely studied and applied in the field of finance [6], management [12] and marketing [8].

With the rapid development of e-commence in the last decade, signaling theory has been introduced to the online world. In e-commerce, a signal conveys information about a product with unobservable quality to buyers [68]. When buying a product in a physical store, the quality of a product is generally observable during the browsing and selection process. However, the context of online shopping sites prevents buyers from directly observing and assessing the quality of products; instead, they often need to make the decision of purchasing certain products with limited information provided by sellers online. Prior research in the area of e-commerce found that the perceived quality of a product based on the signals provided by the website such as reviews will positively affect a consumer's intention to purchase the product [78]. The kinds of clues provided by the signal, the credibility of signals and the level of uncertainty of buyers about product quality are factors that influence the effectiveness of signals on purchase intention.

The application of signaling theory inspired me of using the theory in the context of hybrid communities. Similar to e-commerce websites, the problem of information asymmetry exists in the context of hybrid communities. What happens offline is only visible to members who physically attend offline activities, but often not for others who have only joined and

participated in the community online. For new members who did not have prior offline experience in the group, they need to make the decision of attending an in-person event with limited information. In hybrid communities like Meetup groups, the event organizers and members who have attended similar events in the past can be considered as signalers. Having them to convey positive signals about the past offline activities organized in the community to potential members could be a practical strategy to overcome the challenges of information asymmetry and help them make decisions to participate in the community. In my dissertation, I argue that cross-boundary artifacts have the potential to become signal carriers which help signalers to encode information and allow receivers to interpret the quality of offline interactions in hybrid communities. Hence, one of the main goals of this dissertation is to investigate the role of cross-boundary artifacts in communicating signals of offline interactions. What kinds of signals can it convey? Can receivers correctly interpret those signals when receiving those artifacts? How do those signals further impact their decision making process? Utilizing the signaling theory as the framework of this dissertation, I designed and conducted both a two-step project to answer these questions.

While signaling theory has been widely applied in related fields to convey signals about product quality via advertisements or online description and comments, we still have little understanding about what signals can be conveyed by cross-boundary artifacts, especially visual artifacts such as event photos in hybrid communities. Unlike text-based artifacts such as online comments, in which positive signals may be easily encoded by textual description of events, visual artifacts may contain latent signals about offline activities such as the group dynamics or the environment of a venue. To understand what kinds of signals can be conveyed by visual artifacts, I conducted an online study (Chapter 5) to understand how receivers interpret signals by viewing photos of offline activities in hybrid communities. Following that, I further conducted a lab study (Chapter 6) where I manipulated a few signals in cross-boundary artifacts to examine the impact of signals on people's decision making process.

2.3   Sharing visual artifacts in online social systems

Online and digital artifacts sharing has a long history, with much research done on the topic. This has only increased with the rapid development of digital cameras and the advent of social media/networking sites, which have made it faster and easier than ever before to upload and share visual artifacts such as photos online. Photos have been integrated in a number of ways on such sites and become one of the most rich and easy ways for people to communicate through computer-mediated channels [42, 63, 53, 20]. Social networking sites such as Facebook and MySpace allow users to share photos in addition to textual artifacts such as blogs or comments. Sites such as Twitter and Facebook are even now more actively promoting visual content by allowing users to include photos as part of the previously text-based status updates. A number of social media sites designed solely for photo-sharing have also arisen, including: flickr, Instagram, Picasa, Snapchat, etc.

The role of photo in stimulating interactions through photo sharing has been of interest of researchers in communication studies and the computer-supported cooperative work (CSCW) community for a long time. The rapidly increasing popularity of smartphones has massively supported the social role of visual images in terms of conveying messages. By conducting interviews and observations with eleven PC-owning families, Frohlich et al. [24] found that both conventional and digital photos are used to communicate experiences through either face-to-face conversations or computer-mediated channels. In online social systems, prior research also found that people value the opportunity to use photo as a visual tool to communicate. In a case study of Instagram, [59] categorized "sharing" as the most important motivation of people using Instagram. People reported that they are able to fulfill the desire to exchange visions and receive feedback for self-improvement by sharing photos on Instagram. More recently, [37] studied the photo sharing behavior in Snapchat, an ephemeral photo-sharing tool, where individual can share photos with friends and set a time limit for how long the recipients can view them. Their results showed that more than 60% of the respondents reported that they "feel like they are having a conversation when exchanging Snapchat photos." As a semi-public communication platform, Snapchat allows users to share photos with a specific group of people in a specific duration. They also found

that people are less concerned about their self-presentation online as they are more likely to consider the photo taking and sharing in Snapchat as a way to interact and communicate with others.

In the realm of photo sharing in online communities, the content of images and the sharing practice have always been the key attributes to understand people's activities and personality in the physical world. [54, 62, 34, 4]. For example, [34] analyzed the photo shared on Instagram and clustered users into different groups, such as selfie-lovers and food-posters, based on the content of photos they shared frequently. Furthermore, photos shared in online social systems have become an important media for understanding and expressing the intricacies of human life in relation to situated experiences in the real world. For instance, [48] found that online photo sharing is increasingly playing a more significant role in disaster response and recovery efforts by elaborating on the ways in which members participate during times of disasters. Based on the findings from a qualitative study of 29 groups across six disasters on Flickr, researchers found the content of photos captures physical features of the disaster over time including hazards, post-impact response, missing person and related resources and repository of personal belongings as well as features of social convergence that occurred at the geographical site of the disaster. Moreover, by extracting the textual and visual features of online photo collections, researchers were able to retrieve photos that were associated with social events that happened at specific geographic location and time [9].

The content of photos shared in the community can also influence the reactions of audience in the community. For example, some prior work showed that whether there are human faces presented in photos indicate significantly differences in terms of the reactions of others as audience in the community towards the photos [54, 4]. According to another more recent study conducted on Instagram, [4] found that photos shared with faces attract more likes and comments from others compared to those without human faces.

In the context of hybrid communities, sharing pictures from events is also a common practice. Such artifacts not only document past events but also share experience of the events with others in the group. While prior research has shown a variety of positive impact of sharing photos in online communities, the role of photos is still under-explored in hybrid communities. It is not clear to what extent the pictures can play a role in increasing users'

understanding of offline activities in the group and what information members can infer from the pictures. Grounded on the findings of these prior work, my dissertation considers pictures as the typical example of visual cross-boundary artifacts and specifically investigates the role of picture on conveying information of offline activities in hybrid communities.

3.0   Meetup: The Model of Hybrid Communities

In my dissertation, I use Meetup.com as the model of hybrid communities to investigate the impact of cross-boundary artifacts. Below, I provide some details about Meetup.

Meetup[1] is one of the most popular hybrid communities. It allows individuals to form and join online local groups with common interests and to organize local events around those common interests. As of December 2017, there were about 35 million users in Meetup. On average, 619,000 events per month are organized by 307,436 groups [2]. Meetup connects people through "events" in both online groups and offline meetings. Each event that happens offline, is organized online. Each Meetup group can have one or more volunteer leaders who take the roles to organize and coordinate events in the group (i.e. organizer, coordinator). The online platform allows presenting event information, such as event description, time, location, and optional additional instructional information for the event, e.g., "how to find us".

As presented in Figure 1, the event page presents the list of individuals who attended the event. Each event has a host (called event organizer) and the host information is highlighted on the event page and her prior hosting activities can be viewed by all group members.After the event time, Meetup.com allows some representation of offline happenings. It allows members to post pictures of the events that are available to everyone in the group, whether they have or have not attended the event. Moreover, Meetup allows online discussions regarding the event organization in the form of comments. The pictures and comments that shared after event time are the focus of my dissertation as I aim to understand their role in hybrid communities to convey information about offline happenings and reduce information asymmetry.

Among different real-world implementation of hybrid communities, Meetup is a noticeable example since it has put some specific efforts in highlighting the online-offline connections. Furthermore, Meetup provides the same online design features to a large number of

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[1]`https://www.meetup.com/`
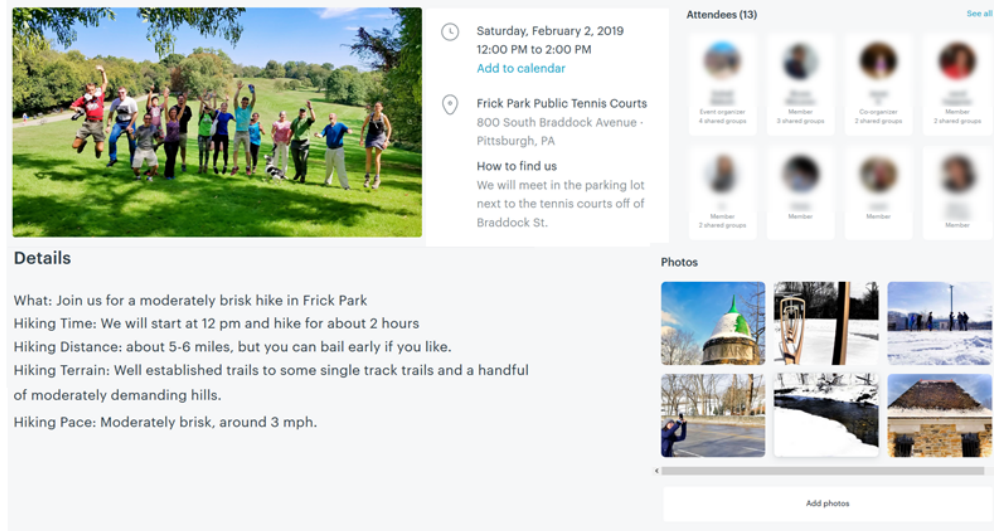
Figure 1: Example event page on Meetup: including event information, RSVP list, and photos posted after the event

diverse hybrid communities that allows researcher to study their research questions within a diverse set of groups. It also provides an easy-to-use API that allows researchers to access all the public Meetup data. These characteristics make it a desirable platform and context to address my research questions. In this dissertation, I utilized the Meetup API[2], and collected data for 673 public Meetup groups located in the city of Pittsburgh PA, for a period of two years (2016 January to 2017 December). I utlized this dataset as the pool for participant recruiting in *Study 1*, the data source for content in the online survey (*Study 2*) and the reference for the material in the controlled lab study (*Study 3*). This dataset also allowed me to obtain descriptive statistics on the current use of cross-boundary artifacts on exemplary hybrid communities.

According to the main topics and types of events, Meetup groups are classified into 33 different categories, varying from outdoor adventure to fine arts and culture. Each Meetup event is a hybrid event happening both online and offline. For example, a hiking event that happens offline, is organized online and involves discussions and comments regarding its

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[2]https://www.meetup.com/meetup_api/

organization. In this dissertation work, we followed a categorization of Meetup group in a prior work[66] and classified Meetup groups into three major types [3]: (1) *Activity Groups*, which includes groups that organize events that allow people to meet for their interests around doing one type of activities together such as hiking, art events, gardening, etc.; (2) *Socializing Groups* refer to groups that were formed without certain goals to accomplish specific activities but for people share same identities or common interests to socialize with each others and build connections through offline events such as vegan groups, language groups, LGBT groups, etc; and (3) *Technical Groups* which particularly organize event around the topic of information technology such as hacking groups, programming learning groups, etc. In this work, we attempted to provide a comprehensive understanding of hybrid communities and the role of cross-boundary artifacts with respect to these three major type of communities and aimed to make the results of this work generaliziable across hybrid communities with different topics and goals.

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[3]We made two changes for the categorization in [66]: (1)included *Hobby* into *Activity* as they were similar events with goals expect the venue is more likely to be outdoor or indoor. (2)combined *Social* and *Entertainment* into *Socializing* as they have the common theme of getting together and socializing with each other.

4.0   Understanding Hybrid Communities

As discussed in Chapter 1, we observed that people's offline footprints in hybrid communities such as the activity they participated in, the interaction they had with other members and the fun they had together are often invisible in the online space. In this dissertation, I argue that the absence of offline footprints will cause *information asymmetry* in the community and digital objects that capture and describe offline happenings can be used to share offline information back to the online space thus bridging the two spaces. Before we explore how to design and utilize such objects (i.e. cross-boundary artifacts) to transfer offline footprints, we lack answers to a fundamental question: Why do online and offline spaces in hybrid communities need to be bridged? Why is information asymmetry critical to the success of hybrid communities?

Several prior works in the field of hybrid communities have discussed its unique intertwined online-offline nature as well as potential challenges to support people travelling between virtual and physical worlds [73, 36, 70, 21, 61]. Yet, few details are available about hybrid communities in terms of how online-offline interaction pattern makes hybrid communities different than other communities in terms of facilitating participation. In particular, why do we care about presenting offline happenings in the offline space? How is it related to people's motivation of organizing and participating in hybrid communities as well as their evaluation of success.

I argue that the unique characteristics of hybrid communities require us to re-visit these fundamental questions. What we knew for online communities can not be directly translated into the context of hybrid communities. For example, for traditional online communities such as Wikipedia or Facebook groups, the success is often defined as the amount of online participation. However, supporting people's travel between online and offline spaces are essential for hybrid communities. With people only interacting in the online space, such communities are merely online communities but not "hybrid communities" as we defined in this dissertation.

Moreover, "more is always better" is a commonly used guidance for researchers and de-

signers to assess or build successful online communities. More members, more contributions, more connections, more interactions are always viewed as necessary ingredients for the success of online communities with considerations of the quality of work [51, 69, 13, 38, 30]. However, such ingredients are not always an option in hybrid communities. In particular, attracting as many people as possible to attend more offline activities is sometimes impractical and unfeasible. Members' offline participation often rely on (1) members' availability for physical attendance or (2) the physical limit of event location capacity. As an example, members may only be able to attend a few number of offline activities which happen near their neighborhood every month. Further, for a lunch meeting at a local restaurant, it is often not possible to have a huge group of people to join due to the location capacity even if there may be many people interested. These barriers of physical attendance leads to members' less autonomy of their participation in hybrid communities.

Furthermore, unlike in Facebook groups or Wikipedia, convincing members to participate might not be enough to increase participation and further make the community success. Instead, there are multiple interaction factors in play. For instance, the leaders or core members of hybrid communities who take the responsibility of planning and organizing offline activities act as an important role in making the community sustain and succeed over time. Without the effort of organizing and hosting, even if the level of interests of participating in offline activities is high in the community, offline interactions can never happen.

Given that we have very limited understanding of hybrid communities from the literature, I adopted an exploratory method by conducting interviews with twelve event organizers of Meetup groups. They can be considered as core members who both actively host events and participate in the group. Our interviews start with exploratory questions to gain a comprehensive understanding of their motivation and experience in organizing events in their group. In the second part of the interview, we focus on people's perception of success as well as practical strategies that contributed to their successful experience. At the end, we asked interviewees about their explicit experience with cross-boundary artifacts in their groups.

In the rest of this chapter, we describe the methods we used to explore the design space and opportunities for cross-boundary artifacts in hybrid communities, discuss the results of

our study and conclude with a discussion of our findings.

4.1 Methods

4.1.1 Participation Recruitment and Description of interviewees

We recruited interviewee from Meetup groups. I used the public API provided by Meetup.com to collect those information of all public Meetup groups in the city of Pittsburgh in order to filter and target potential interviewees. To get a better representation and coverage of the group characteristics in our data, I intentionally balanced interviewees from groups with diverse topics and member size, thus the process of recruitment was iterative and targeted. I sent in-site messages to invite 150 potential interviewees and at the end, twelve of them volunteered to participate in the study.

Of the twelve interviewees (see Table 3 [1]), five of them were female. They were all event organizers from twelve distinct groups [2]. We have a balanced distribution in term of the type of group in which they actively organize events (Activity group: 4; Socializing group: 4; Technology group: 4). The size of their groups (number of members) ranged from 324 to 7043 (Median: 1120; Mean: 2133.3; SD: 2144.2). interviewees' tenure of organizing events in their groups varied from 4 months to 8 years and their frequency of organizing is in the range of almost once every quarter(0.24 events per month) to more than one event per week in average(4.5 events per month).

4.1.2 Interview Process

Interviews lasted between 45 minutes to 75 minutes. The majority of them (10 out of 12) were carried out over video conferencing tools such as Skype or Google Hangouts, and the other two were conducted by phone calls. The interviews followed a semi-structured format and consisted of three major parts: *Motivation and goals*, *Recent organizing experience with*

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[1] All names of the interviewees and groups are removed to protect interviewees' identity.

[2] While five of our interviewees had organized events in more than one group, the interview was conducted by focusing on their experience in the group that are listed in Table 3

Table 3: Basic Information about interviewees and groups that they organized events in.

Interviewee	Gender	Group type	Group size	Tenure of organizing events	Frequency of hosting event (# of events per month)
P1	Male	Activity	7043	4 years	4.5
P2	Female	Socializing	785	7 years	2.47
P3	Female	Socializing	3462	8 years	0.42
P4	Male	Activity	1455	6 years	1.2
P5	Male	Activity	5068	1.5 year	0.25
P6	Female	Socializing	333	1 year	4.14
P7	Male	Technology	2975	4 years	3.48
P8	Male	Technology	514	3.5 years	0.32
P9	Male	Technology	324	2 years	0.24
P10	Female	Technology	772	4 months	1.62
P11	Female	Socializing	2190	3 years	0.54
P12	Male	Activity	679	2 years	0.24

success measures, and *Practice of using cross-boundary artifacts.* Each interview session starts with an exploratory part in which we aimed on understand what drives interviewees to start organizing events and what they wanted to achieve from doing so. We asked each interviewee questions such as:

> *"When did you start organizing events in [your group]? Do you still remember that first event and how did it go? Do you remember what made you start organizing events in [your group]? What were you looking for by becoming an event organizer in the group?"*

We then asked our interviewees to recall their most recent experience of organizing an event in the group. In particular, we focused on how they evaluate that event as well as the strategies they adopted and challenges they encountered in organizing that event. Specifically, we asked them to assess *"how did that event go? What went well and what did not?.* Also, we directly asked them whether and why they considered that event as an successful one or not as well as what are strategies they thought were effective in making such event successful or would have made the event more successful. While those questions allow us to hear interviewees' spontaneous expression, a set of candidate measures of success informed by literature and the hybrid participation pattern of Meetup groups was also presented to interviewees and they were asked to assess whether those factors are important for them when assess their events. The candidate measures include:

- Number of attendees
- Number of old-timers attend in the event
- Number of new faces show up in the event
- Degree of interactions among event attendees offline
- Number of people comment, send messages about that event
- Degree of interactions among members online

In the last part of the interview, we asked our interviewees about their past experience of sharing or viewing cross-boundary artifacts in their groups. We were interested in whether there are any particular challenges than hinder their use and if they can prospect any potentials of using such artifacts to benefit their experience or the group overall. A detailed interview script is included in Appendix A.

4.1.3   Data Analysis Approach

All interviews were recorded and transcribed, which results into approximately 12 hours of interview data and a total of 145,992 words of transcription. We used qualitative data analysis software (Atlas.ti) to conduct the first round annotation, which follows an open coding method used in grounded theory [29]. We started with initial and thorough readings of the transcripts and wrote down patterns or themes noticed and assigned preliminary annotations to those raw data. We then organized those annotations through card sorting practice in a team and code them around motivations of organizing events, success metrics, procedure of organizing events, challenges and strategies to organize successful events as well as experiences and perception of utilizing cross-boundary artifacts in their group. The codes were refined and coalesced into higher-level categories and the common themes were extracted based through an iterative process. We discuss the results of our analyses in the following section.

4.2   Results

In the following sections, we discuss the results of interesting and common themes that emerged in our data analysis process. The results included motivations and goals for organizing events in hybrid communities, perception and assessment of success, strategies and challenges in organizing successful events. In summary, we found that **offline interaction is the core of hybrid communities** for two reasons: 1) People are motivated to organize and participate by the opportunities and subsequent benefits of offline interactions; 2) Quality of offline interactions is the key metrics of success in hybrid communities. Moreover, organizers often judge the quality of offline interactions by on-site observations. Further, sharing pictures of offline events can help set expectations of future events but organizers also expressed their concerns about how much information pictures can convey and how important it is for attracting future participation. Below, we demonstrate the key findings in details.

4.2.1 Offline interaction is the key motive to organize and participate

Our results of the interviews showed that people are motivated to organize and participate in hybrid communities by the opportunities to interact, connect, grow and contribute in the physical worlds. Online interactions are not the purpose of these communities, people volunteer to organize events in their Meetup groups so that they have opportunities to interact with others in the offline spaces, as stated by P12:

> *"I don't think it matters if people chat online often or not. **It is not the purpose of this group**. Meetup is for us to really meet and do things together. **If there is a lot happening online but no one comes to my events, it is meaningless**. As long as people come to the event and we had a great time together, I would be happy with it."* [P12]

According to the motivational framework in domains such as voluntary studies or online communities, people are motivated to participate in those organizations by concerns for self (egoistic motive) and others (altruistic motive) [11]. Similar results are observed in our study, where we identified two major factors that motivate individuals to utilize hybrid communities to host events in the local area, from more egoistic perspectives as(1) *taking advantages of local opportunities for **personal needs***, to more altruistic reasons as (2) *contributing to **local communities***.

4.2.1.1 Taking advantages of local opportunities for personal needs
Ten out of the twelve interviewees reported that organizing events in hybrid communities have empowered themselves to take the advantages of local opportunities and further fulfill a variety of personal needs from (1)*finding social companions*, (2)*establishing social relationships*, to (3)*facilitating personal and career growth*. Hybrid communities allows event organizers to take advantage of its technological features such as searching among a large number of people with similar interests as well as advantages of face-to-face offline interactions such as developing strong interpersonal connections with a group of people within nearby geographical areas or leveraging knowledge and information in local spaces.

Finding social companions. According to our results, *looking for companies with similar interests* beyond their personal social networks has been an essential goal for event

organizers, especially in socializing groups and activity groups. For instance, P2 described why and how she started the "book club" events in a regional socializing group on Meetup:

> *"**I love to read and I've always had an interest in having a book club**. So I put up on the discussion area of our website if anyone else thinks if they would like to have a book club. And I had very positive results, so we now have been meeting for three years, at least once every month."* [P2]

P11 also explained how organizing dinner events on her Meetup group opened up new experiences to her without relying on her core group of offline friends:

> *"**I am more adventurous than some of my core group of friends are**. Like I love trying new restaurants and new places and some of my closest friends, they really just want to go to the same places all the time. So **if a new restaurant opens up in Pittsburgh and I want to try it, I could post it myself on [the Meetup group] and I might be able to get 15 or 20 people to go out to dinner with me. I don't have to rely on my core group of friends to try a new restaurant.**"* [P11]

Establishing social relationships. Furthermore, organizing events using hybrid communities have also helped organizers from finding a group of people to do interesting things together, to *form actual social relationships* with them in the physical world so that expanding their personal social network, as said by P6:

> *"The goal (to start organizing events in the group) is just connecting people and then also for myself and also my husband who runs the groups with me, **it's a way for us to connect to other people**. I moved back to Pittsburgh from Denver a year ago, and I think we just like it 'cause it's social networking and meeting new people. "* [P6]

Making friends and expanding social network can be an even more explicit reason for people to start organizing local events through hybrid communities, as the story told by P2:

> *"The reason I started (organizing events in the group) **in the first place is that I was an empty nester**. My daughter had grown up and left home. You know at an older age, **it's hard to make new friends**, ...my daughter had told me about Meetup. I started going to events in other area of the city, and eventually **I started my own group in my neighborhood and it really has become a community for me and a real way of making friends**. And I really have friends that I have met through my Meetup events..."* [P2]

Facilitating personal and career growth. Unlike those social factors that we observed which motivate event organizers in socializing and activity groups, we found that

career and self-enhancement motives serves a more important role in encouraging people to organize local technology events utilizing hybrid communities. According to Clary et al.[14] , *career motive* motivates individuals who believe that their participation will improve career prospects and the *self-enhancement motive* serves to enhance a volunteer's personal sense of distinction and importance. Three out of the four event organizers we interviewed from technology groups viewed the opportunities of learning knowledge or information from face-to-face meetings with local speakers, companies or technology communities as their most important motivation to organize technology events using hybrid communities.

For example, P7 stated that organizing local events within the hybrid communities is a mean to keep the connection with local community and benefit his professional career:

> *"Now **a part of my official duties with my current employer, is to be active in the community**, and be actively finding people to come work for us. Being a semblance of a thought leader in that community. **People see me, they associate me with [the Meetup group] and [my employer]. And, [my employer] gets to be a little more well known in the local community"** [P7]*

Similarly, P8 also pointed out that organizing technology events by their Meetup groups allowed them to stay updated with knowledge, information and trending technology from the local technology community:

> *"I met great people in the community who I learned from and we always exchanged cards and 'Oh my gosh, what are you guys doing?' And **I learned so much about others and other companies and what kind of technology they're using.**" [P8]*

4.2.1.2 Contributing to local communities

In addition to fulfill a variety of personal needs, our interviewees also reported three altruistic reasons for them to utilize hybrid communities to organize events in the local area and eventually benefit the local community, including (1) *Filling the "missing hole" in the local space*; (2) *Giving back to the local community*; and (3) *Maintaining a sustainable local resource.*

Filling the "missing hole" in the local space. First of all, an interesting thing to note is that hybrid communities like Meetup groups enables individuals to discover the missing types of activities, topics or groups in their local area by searching and comparing the existence of events or groups between different geographical areas. Five of our interviewees

claimed that they observed those type of *"missing holes" in the local space* and decided to contribute and fill it. As an example, P1 started to organize his own hiking events in one of the hiking groups he belongs to because he realized that there was no hikes ever organized in parks to the northwest of the city where he knew pretty well.

> *"I live in [an area] of Pittsburgh. So **there aren't, or there haven't been, a whole lot of events that were posted for this area**. And there's a city park, [park name], that I've gone to for years and years and years. And I decided I can do it. **I've had gone hiking there and knew different paths and trails that I wanted to share with others**. I would go ahead and step in as an organizer."* [P1]

Moving to a new city can also facilitate people who have been engaged in hybrid communities while they were in other cities to easily find out missing events or groups in their current local community. For example, P6 started to organize happy hour events in her community as she used to do it in Denver and missed such events after moving to Pittsburgh.

> *"This group is **an extension of a group that previously ran in Denver**, so I started the [group name]" in Pittsburgh **because I saw that was something that was missing**, that we didn't really have been organizing such events here.* [P6]

Giving back to the local community. Organizing certain types of events to fill in the empties in the local space is one way to diversify and enrich event categories in the local communities so that it allows people to be brought together and connected through attending more possible events provided to them. Furthermore, we found some of our interviewees expressed more explicitly about their goals to contribute and *give back to their communities* by utilizing hybrid communities to organize local events. As an example, P5 from a hiking group accounted his willing to organize local events as a way to give back to their local communities given what they have gained in the past.

> *"I mostly for the first two years was primarily as just an attendee... but then **it got a point where, one, I knew how good the groups and the events had been for me for my own mental health and physical health**...So I really decided to take that leap of asking to be an organizer in some of these groups **in order to both pay back, pay it forward, and then give back to the experience so that other people could hopefully gain what I have gained.**"* [P5]

Maintaining a sustainable local resource. Organizing events in hybrid communities is not only an opportunity to show the care for local communities, but also a way to

maintain a collective resource for the local community. Some of our interviewees volunteered themselves as event organizers and continuously hosting events in the group simply hoped to keep the group active and maintain it as a sustainable resource for the local community. For example, P10 explained why she decided to step in as the primary event organizers in the technology group she has been engaged for years:

> "... I think that civic hack is really important, like in all regions of the world. So I think **keeping [Meetup group name] would be a big blow to the area**. Few months ago, the previous organizer of [group name] stepped out so I, together with my friend [name], decided to take charge as the event organizers in the group so that the group wouldn't get off. **We make sure that people who are interested in improving local issues can network and find the resource that are available to them to help them solve those problems.**" [P10]

P4, as a popular event organizer in a hiking group over many years, has met many friends with same interests and could have just organized hikes by contacting those close friends off-Meetup. However, he claimed that he continued to host events utilizing hybrid communities frequently in order to maintain the hybrid community as a local resource for more people to discover and participate in hikes in the local area as long as they are interested to do so.

> "**It's not a matter of being necessary for me. I do it because I feel there's a need for it**...I have found, surprisingly, **the majority of the people who are interested in these events are women**, it seems like. So they really appreciate the chance to go out and do stuff, to get and be safe ... **They're not gonna go out and do a night hike by themselves. But if we get together 12, 15 people, they feel very comfortable, doing that.**" [P4]

4.2.1.3 Hosting fulfills more desires in offline interactions than just attending

With respect to the motivations we discussed above, especially for personal needs, it seems that individuals may also leverage local opportunities to fulfill them by simply attending events posted by others in hybrid communities. Hence, we also probed the particular reasons for individuals to organize their own events rather than attending events hosted by others in the interviews. We asked our interviewees to think of the start of their hosting experience and share why they feel the needs of organizing their own events. As a result, we found that hosting instead of attending fulfills more desires of offline interactions in two major ways.

First and foremost, while organizing your own events means a lot more work, it empowers organizers to *take full control over the offline interactions*, including deciding topics to discuss, activities to take, guests to invite, time and location to meet, etc. For instance, P2 stated:

> *"It's definitely a lot more work to have your own events, but it also is nice because maybe I say to myself, I really would love to have some Chinese food, so let's schedule Meetup at such and such Chinese restaurant."* [P11]

Moreover, hosting an event also allows individuals to be the centre of the stage and lead the procedure of an event. Therefore, some interviewees considered organizing events as a way to *build their personal reputation in local communities* and show off your knowledge. P5 and P12, who are both event organizers of activity groups, admitted that they see hosting an event by themselves really showing off their experiences and knowledge to others.

> *"I've been passionate about outdoor activities for many years and hosting events in the group is just a way to make the best use of my knowledge and expertise. I like to **be the leader and help others who are also interested in outdoor adventures** but maybe with less experience to get more chance to go into the nature"* [P12]

Similarly, the event organizer of a technology group, P7 mentioned how hosting events in the group allows him to build personal reputation in the community.

> *"**From hosting, I get an association with the topic**. I recently hosted an 'Introduction to Spark' talk. My company uses Spark extensively. **Having my name associated with Spark, having my name associated with that presenter, having [the group]'s name associated with it, just raises the profile of everything.**"* [P7]

4.2.2 Quality of offline interactions is the key metric of success

In the previous sections, we showed that people are motivated to organize and participate in hybrid communities by the opportunities of offline interactions. Our interviews also aim to investigate the role of online and offline interactions in terms of how people evaluate "success" in hybrid communities. Our results show that the offline participation was more decisive than online participation when evaluating the success of hybrid communities. Furthermore, interviewees value the qualitative aspect of events according to attendees' of-

fline experience (e.g., did people enjoy the event?) much more than the quantitative aspects of the participation (e.g., how many people attend the event?).

4.2.3 "Online interaction is not a measure for success"

When we asked our interviewees to recall the most recent event they organized and assess whether it was successful, none of our interviewees mentioned about online participation such as number of comments, number of RSVPs or number of photos as indicators of event success. Instead, all of them focused on people's offline participation behavior when explaining why they considered their events as successful or not. As an example, P9 explained that the degree of online interactions is not a metric for him to assess the success of his event as his goals is to ensure a good offline experience.

> *"It's good if people leave comments after the events to give feedback or just write a 'thank you' message. But **I don't expect people really have much meaningful interactions through comments**. There is a discussion board in the system too, but we never really used it. **There is really not much to interact or communicate online** except asking and answering some clarification questions before the event. My goal is to make sure people enjoyed the event and find it useful. That's all I care."* [P9]

4.2.4 Quality of offline interactions is the key

Regarding what defines the success of their Meetup groups, the most common theme that we heard from interviewees is that *"the quality of the offline experience is much more important than the quantity of attendees."* Interviewees definitely emphasized the experience of attendees during events as the most critical measure for the success of their events while having a mixed attitude towards the quantitative measures of events.

Quality over quantity. According to our results, all of our twelve interviewees asserted that everybody who attended their events had an **enjoyable**, **engaging** and **interactive** experience was their primary goal and most important indicator for a successful event. For example, P11 considered the most recent socializing event she organized was successful due to the fact that all attendees interacted with each other and enjoyed the event:

> *"I thought I was really successful. **We had a really good time**. [Venue name] gave us a very nice space where we could meet and talk. And **everybody enjoyed themselves**. I*

thought it was very successful. **Everyone had fun.**" [P11]

P3 also explained how she evaluated networking events as successful or not, based on the interactions, conversations and takeaways people gained from the event.

"*Since it's a networking event, my expectation or what I hope for in the event is that* **people meet each other, they connect with each other, they have like meaningful conversations with each other**, *and I think that one of the best things could be* **somebody finds a job through the event, or somebody finds friends, or somebody finds some important information in the field that they were looking for**, *anything like that, I think that's like a good event, a successful event.*" [P3]

More explicitly, some of our interviewees emphasized that they would **not** evaluate whether their events are successful based on the number of people who show up in their event; instead, they care much more about the quality of the experience. For example, P4 stated:

"**I don't qualify a successful event based on how many people show up**. *I could have a successful event with 40 people or with four people. I look at what was the experience of the people who were there and the people who attended.* **I think every single one of them had a really great time and that to me is success** *and that makes me feel really good and it just makes me proud of my Meetup group and proud of my members.*" [P4]

"More is not always better." Our interviewees not only reported the marginal importance of the number of attendees, but also raised their concern on the possible negative effect of large group size on the quality of event experience due to the physical limit of event capacity. In that case, organizers often put a cap to limit the number of people who can attend the event and it happens mostly for socializing and activity events. For instance, P5 described his perspective of limiting event size in order to ensure the experience of attendees:

"**I do put limits in, and I don't subscribe to, 'The more, the better.'** *I decide the limit depends on what type of trail we're gonna be on.* **If the thing's a track trail, you don't want a whole lot of people**. *It's going to be a very, very hilly, very hard hike.* **The more people you have, the slower you go.**" [P5]

P6 from a socializing group also explained that she had to put an attendance limit of 12 people for her recent event due to the capacity of the venue and the form of the interactions they desired during the event:

"If you get many more than 12 people it becomes very cumbersome. You can't talk. Everybody can't sit together. 12 is the number of seats in the private room at [name of the venue]. If the table gets bigger than that, it just doesn't work. Nobody can hear each other. It's just in no way shape or form is it as fun. " [P6]

4.2.5 Mechanisms to assess quality of experience

While all interviewees stated the importance of attendees' offline experience, we were interested in what mechanisms they use to assess it. The majority of our interviewees (9) reported that **on-site observation and communication** was the main method they used to get a sense of whether people were having fun. For instance, P7 explained he would actively observe whether everyone in the group was engaged with the talk he organized in a technology group:

> *'I think what's really helpful is to have it in a workshop format because they require people to talk. I can tell from the back of the room to see if people were engaged in conversations or just on their phones."* [P7]

Intriguingly, P6 from a socializing group described how she noticed that people were enjoyed as they interacted with each other and stayed longer then expected:

> *"I think the majority was just **observation of people connecting and people tend to stay a lot longer than the event goes for, so people weren't leaving earlier**, they were there I think an hour past the event."* [P6]

More interviewees reported that they seek feedback from attendees during the event in addition to passive observations. For instance, P11 introduced how she actively seeks feedback throughout the entire time of the event:

> *I'll walk around and ask is everyone having a good time and at the end, I'll walk around and ask did everyone enjoy their meal. So **I try to interact with the people who are there at least a few times throughout the event and try to get feedback from people** and if there is a problem, then I can address that with the restaurant and the staff as well."* [P11]

While the majority of our interviewees prefer in-person observation and communication, we did find that *online channels* such as in-site comments, emails or other out-site messages were used to as additional channels to receive feedback, as suggested by the quotes below.

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*"I sometimes **check if anyone comment on the meetup afterwards, because that shows community engagement**, it shows people are interested about it. And it shows people are still thinking about it. **It sticks with them after they leave**, right? They're still thinking about the meetup. "* [P8]

*"Sometimes people will **leave comments on the event page afterwards** like, "Had a really great time. Thanks for organizing." I will **occasionally get private emails from people** thanking me for organizing the events."* [P12]

However, interviewees reported that the *quantity* of such feedback cannot be used as a reliable proxy to determine if a good proportion of attendees enjoyed the events since the number of people who leave feedback online is generally low, as described by P7.

*"We have tried to measure **how much activity is on Meetup after the event, people discussing things, how much activity is there on Slack after the event** as we use Slack for community chat. However, those things, **they're not really good indicators (for success) 'cause very few people post** afterwards. "* [P7]

4.2.6   Strategies in organizing successful events

We have presented our results about why people build hybrid communities and how they evaluate the success in this context. Now, let's focus on the process to make hybrid communities successful. In particular, we were interested in strategies organizers adopt in making their event successful. As a results, we found our interviewees made efforts to mainly ensure attendees having a satisfied offline experience. In order to do so, they (1) utilized the online space to *set the expectation* for an event before the event time, (2) *Leading offline interactions* during the offline event; (3)*proactively collected feedback* from attendees during and after the event.

4.2.6.1   Set the expectation beforehand is important.   During the interviews, we asked our interviewee to recall their past experience of organizing events and answered questions such as *"What did you do in order to make the events you organized successful? Do you have any specific routine or strategy for organizing successful events? If yes, how effective do you think they have been?"*.   Our results showed that prior to the event time, organizers invested most of their effort to set up a clear expectation for potential attendees about the

upcoming events. They believed the clear expectation can help people to self-select events that best fit their needs or to prepare themselves with the understanding of what is going to happen in the event and what they would gain from attending it. For instance, P4 as an organizers of activity group, stated the importance of communicating the expectation by writing correct event description and how it can help make people satisfied with his event even under a bad weather condition.

*"It's important to **make sure communication is adequate, so people aren't going to come and not to have an experience that they weren't expecting**. It is more about making sure that my write-up is correct. For the last weekend event - the weather could have been less muddy. But I prepared for that by letting people know that. We got to a point where it was going to get very, very muddy, but we were all prepared and I had a shortcut that they could take. And it turns out to be a really good event where everyone was having fun and went through it together."* [P4]

P2 from a socializing group further explained the it is worth to make sure everyone knows that what kinds of interactions and what kinds of takeaways they can expect for any upcoming events so they can make better decisions on which event to attend, and will not come to an event and find out they don't like it. She gave an example of her book club events, in which they tend to be more socializing and less focused on the book. Thus, people who are expecting more book discussion will be not satisfied with those events.

*"It really does not matter whether people read the book or not. We don't spend a lot of time talking about the book or analyzing it. But it is a group of ladies that have come to really enjoy each other's company. I think **sometimes people come and expect a very sophisticated book discussion, and we're very much not that**. So if that's what they're looking for then there's lots of book clubs like that. And they can find something else that they can enjoy."* [P2]

However, some of our interviewees also felt difficulty in describing offline events in ways to make it informative for those who have not attended any events before. P5 expressed how he felt it's sometimes difficult to write a good event description that can make members who have not attended any events to totally understand offline happenings.

"I think some people are really shy and nervous about coming to their very first Meetup event and there are very little about the environment and dynamics that you can imply just from the description. So maybe until you've attended your first event, you just don't understand." [P5]

P6 also shared her thoughts about better describing the positive social atmosphere in her group for people who might want to participate for their first time.

"Maybe I can do a better job conveying that to people who haven't attended, saying, 'Just want you to know, everybody is really friendly and open and welcoming.' So that those new members would be more inspired to attend." [P6]

4.2.6.2 Leading the offline interactions during event is the trick for success. As offline experience is the key measure for the success of event in hybrid communities, organizers paid a lot attention on making their event more welcoming, engaging and inclusive. Our interviewees reported various tips they often adopt to make a better experience for attendees during their events. The overarching strategy is to actively lead the interactions during the event to help attendees feel comfortable and enjoyable. Specifically, they often make sure to greet and welcome everyone, kick off the introduction among attendees, and proactively interact with them and fulfill their needs timely if possible. For example, P8 shared how he often greet people to make them feel welcomed and further help people to connect with each other during his technology events.

"I always try to greet everyone, I think that's really important... **I always try to connect people, so if I talk to one person, and I met somebody else that I think will be a good person for them to talk to, I introduce them as much as I can.***"* [P8]

Moreover, P1 as an organizer of activity events, reported that he doesn't ask people to formally introduce themselves, but he will always try to periodically observe and check in with everyone during his hiking event. If he find anyone who is alone or behind, he will always try to be on their side and interact with them so everyone will feel inclusive.

"it's very informal ...it's up to them to introduce themselves and go talk to other people. but I will always try to make sure that no one is alone or too much behind others. In those case, I will most likely just go and talk to them. While it is a hiking event, I don't like people to feel isolated. It's a group event, so I want to make sure everyone is part of it." [P1]

4.2.6.3 Seeking feedback is useful to make improvement for future events. As discussed in section 4.2.4, organizers proactively seek in-person feedback from attendees during the event time and use online feedback as additional source to evaluate the success

of their event. Further, our interviewees also stated that seeking feedback about the events is a useful way to learn what needs to be improved for the future events. For example, P11 described how he have changed the logistics of a recent socializing event based on the feedback he received in the previous events.

> *"**If I found out something's wrong in one event, I try to fix it in the next one**. For instance, in one of our events there was a room with lots of tables, and everyone was sitting at the tables, and some people told me that they didn't get a chance to interact with a lot of other people 'cause they were stuck sitting at tables. So the next event, I moved the tables away, and everyone was standing so they could move around and it was more interactive."*

Furthermore, our interviewees expressed the potential benefit of systematically collecting feedback of events over time which can help them to figure out the best time, location and topics for events if they can relate the feedback to such event characteristics. However, they were not able to do so because the lack of mechanisms or tools on Meetup to systematically collect, store or even analyze such data. As P7 from a technology group said,

> *"It will be really helpful if we can **track how people feel about each event over time**. Then we will have a great dataset to figure out what kinds of events, or maybe what kinds of place are the ones people like the most. I wish we had those data but unfortunately we could only rely on our own judgment based on what we hear from people during each event. It can be more difficult as we are getting larger and more events are organized. It's hard to get an overall sense. "* [P7]

4.2.7   Practice of utilizing cross-boundary artifacts

In the last part of our interview, we asked our interviewees about their past experience of sharing cross-boundary artifacts in their group. Especially, we focused on posting photos that were taken during their events back to the online platform of Meetup. Six out of twelve mentioned they have posted photos for their events. However, only one of them reported that he posted photos regularly for almost every event he organized, and the rest just occasionally did so. Yet, all of the twelve interviewees admitted that they would hope to have more photos shared in their groups. Below, I summarized the our results about the perceived functions of sharing photos in the group as well as the concerns that hinder organizer from taking and sharing event photos.

4.2.7.1 Perceived functions of sharing event photos   Our interviewees reported two major functions they perceived of sharing event photos in their groups, including (1) *helping to set expectations of future events*; and (2)*building profile of the group.*

As discussed in the section above, setting expectations of future events is important for people to know what the upcoming event will be like and allow them to select the event that fits their needs and to prepare themselves with the event if they decide to attend. While event description was the main entry where organizers made a lot effort to set clear expectation of an upcoming event, our interviewees acknowledged the potential of using photos of past events as the carrier to communicate what to expect in future events. For example, P3 explained how she feel that event photos could help new members to the group to know about the atmosphere of their events and imagine getting similar environment if they attend upcoming events in her group.

> *"A picture is worth a thousand words. I should definitely be posting more. I feel it is more* ***useful for new members in the group who have no clue about what kinds of people we are and what our events look like****. The photos may be* ***better expressing the friendly atmosphere*** *of our events than any words. "* [P3]

Another function that some of our interviewees perceived from sharing event photos is to build a better profile for the group. It will present a better image to attract participation from new members. For instance, P9 explained how photos can give credibility to the group as showing the attendance level and interactions among attendees.

> *"It shows hey there are lots of people coming out and working together. If one of your reasons for attending meetups is to meet up other people, you want to go to one where you're going to have a good chance of meeting and talking to a lot of folks. So kind of* ***showing the room through the back and how well it's attended, I think that gives some credibility.****"* [P9]

Further, P11 described how photos can be a good indicator showing that the group is active as offline events are really happening.

> *"Photos are really just a good way to market your group.* ***A group that has no photos in it may seem very inactive.*** *Once you have up some content and some photos, people can see some of them, I think that's enough for somebody to really see this group is meeting, people are there."* [P11]

Building the profile of groups using event photos will not only benefit in attracting future participation, but also create the memories for people who attended the event. P6 mentioned about the potential benefit of having event photos to commemorate past events happened in the group.

*"It's just a fun way for the people who attended the event to remember it afterwards and remember the friends that they made and the conversations they had and the food they ate and the restaurant they were at. It's just **a wonderful way to just commemorate the event.**"* [P6]

4.2.7.2   Reasons of low use   While our interviewees acknowledged the penitential benefits of posting event photos in their group, we found two main reasons that hinder them from doing so. First of all, our interviewees worried being distracted from the interactions during events by taking photos, especially those from socializing and activity events.

P5 from an activity group that he prefer to experience the event in the moment rather than take time to capture it by photos and view them afterwards.

"I'm just don't even think about taking pictures. I have always felt like I want to be in the moment and experience it more than worrying about recording it using photos during the time and to look at it on my phone when I'm home." [P5]

Similarly, P11 explained that he always forgot to take photos since they were engaged into the offline interactions at the moment and wished someone else could help them to take the photos.

" Sometimes I just forget because I'm into the conversation. I take maybe one or two if I can think of doing it. It will be easier if someone else can help me with it." [P11]

Secondly, our interviewees expressed their concerns about the effectiveness of photos on facilitating offline participation. In particular, they concerned about the visibility of photos to members in the group and the capacity of photos in representing offline interactions. For example, P4 explained that he did not post photos to his events because he doesn't believe people will go through the event photos before deciding on attending an event.

*" I don't think people look at the photos that much. I know personally, I'm not gonna go through all of the event photos of a group. **You have to basically go back to find photos of previous event and that is too much for me.** "* [P4]

Moreover, P3 from a socializing group expressed her doubt about how much meaningful information can be conveyed by event photos of her dinning events and whether it can influence the decision making process for members.

" Our events are mostly very interactive and conversational. I don't think posting a picture of a bunch of people at a table, smiling or talking to each other, is going to necessarily say, Oh I want to go to that group." [P3]

4.3   Discussion

Our results illustrated that **offline interaction is the core of hybrid communities**. People are motivated to build and participate in hybrid communities by the opportunities to interact, connect, grow and contribute in the physical space. They aim to find companies to do things together in the local area. They look forward to building real connections and relationships with people through in-person interactions offline. They hope to take advantages of utilizing local resource and learn from other people to gain more knowledge, skills and social connections to facilitate their personal and career growth. They also want to contribute to the local communities by organizing activities in the real world. Facilitating offline participation is essential for people to meet their goals of building hybrid communities. Hence, to fulfill the goals of hybrid communities, we need to focus on mechanisms that can drive members to participate in offline activities.

Moreover, **offline participation is the key success metric of hybrid communities**. Without having people interact in the physical space, hybrid communities like Meetup groups are meaningless. Unlike traditional online communities, the amount of user-generated content in the online space is not used to measure the success of these hybrid communities. In fact, if people only chat in the online space but hesitate to commit to offline participation, the goal of organizers are not fulfilled so they will not consider it successful. Further, the rule of "the more, the better" doesn't fit in the context of hybrid communities. Instead, **the quality of offline experience is much more important than the quantity of participants offline**. Organizers do not evaluate the success of their offline events based on how many people participate in; instead, they care about whether the event is engaging,

interactive, enjoyable for attendees. Based on the results of this study, we found the success metric of hybrid communities are distinct from traditional online communities. In spite of focusing on attracting more participation, organizers in hybrid communities need to pay more attention to ensure the delightful offline experience.

Our results showed that organizers can gain those information about quality and assess the success of their events mainly based on their observations during the event. However, these important pieces of information that described the success of past events and quality of attendees' offline experience are often invisible for members who did not attend past events. I argue that reducing information asymmetry about offline interactions and communicating the quality of the events back to the online space is vital for building successful hybrid communities. It can support the decision making process about attending future events as well as contribute to the quality of future events. In particular, information that describes the quality of past events can help to set the expectation of future events. From our results, we found that setting expectation is one of the most common strategies organizers adopted to help people select events that match their preference as well as prepare themselves with the upcoming offline activities. Transferring the information about how engaging, interactive and enjoyable the past events were can be utilized as an effective mechanism to help set expectation for future participation. Further, it also increases the chance that people who make their decision of attending an upcoming event with clear expectation will eventually enjoy the event and contribute to make this event an successful one too.

The results of this study also emphasized the importance of designing mechanisms to connect online and offline spaces in hybrid communities. In fact, event organizer acknowledged that cross-boundary artifacts such as pictures and comments can serve the goal of sharing offline experience in the online space. In particular, event organizers perceived the function of sharing event pictures as helping to set expectations of future events and building profile of the group. Regarding their experience with cross-boundary artifacts, interviewees however admitted insufficient level of use. They expressed concerns about the capacity of such artifacts in conveying useful information, their direct impact on attracting offline participation, and the possible distraction from offline interactions during event time. In the following chapters, I present studies that aim to assess the role of cross-boundary artifacts in

connecting online and offline spaces in hybrid communities, with the focus on the capacity and impact of such artifacts on conveying useful information to facilitate offline participation.

5.0 The Capacity of Visual Cross-Boundary Artifacts to Convey Information of Offline Activities

In Chapter 4, we explored the context of hybrid communities with foucs on the blended nature of online-offline interactions. Our results suggested the importance of supporting offline interactions as the key to build successful hybrid communities. It not only means attracting more people to attend offline activities but also ensuring the offline experience of attendees to be enjoyable, engaging and interactive. To achieve this goal, supporting members of the community to find the events that fit their preference at the first place is vital. For a new member or an existing member exploring a new group or a new activity, information about prior events can be essential in making the decision to attend an upcoming event. However, these is often very limited information beyond the formal description of events in the online platform. An individual can be interested in understanding how busy an event gets, how interactive, enjoyable, or fun the event is, or what demographics of people attend the event. Some of this information is available on platforms such as Meetup.com; however, often not very visible and exclusive to members who physically attended those events.

At the same time, a rather common practice on the these hybrid platform is to share pictures from the events or leave comments about the events on the online platforms. Such artifacts not only document past events but also share experience of the events with others in the group. Our results in Chapter 4 showed that event organizers in Meetup.com acknowledge that pictures and comments of past events can help future participants to set the expectation of future events. In particular, they believe sharing visual artifacts such as pictures in hybrid communities can help to increase the awareness about the offline activities and build a more attractive and credible image for the group in the online space to engage future participation. As the old saying goes, "A picture is worth a thousand words". However, in the context of the online-offline hybrid communities such as Meetup.com, it is not clear to what extent the pictures can play a role in increasing users' awareness and what information members of these platforms can infer from the pictures. Lack of confidence in utility of pictures in

representing offline happenings was one of the major reasons not to invest efforts in taking and posting photos in their groups.

However, these information about what happened in the past can communicate a number of signals about the events to support members to make decision about attending future offline activities in the group. As explained by signaling theory, we rely on signals to assess the quality of the situation in decision making process [16, 18]. Pictures are a form of non-verbal communication that can include a number of cues about the events to support decision making process. In the context of attending events, one can assume that an individual will search for the following signals to assess the quality of an event:

- **Event topic and whereabouts of the event**: How desirable is the event and where the event will be happening?

- **Social dynamics of the event**: How enjoyable and pleasant is the dynamic of the interaction among participants during the event?

- **Events' success**: How successful the event is, in attracting members to attend, and providing a pleasant experience for those who attend?

The goal of this work is to systematically study which signals can be communicated through the pictures, what kind of information such signals can convey, and how reliable these signals are to support users' assessment of the quality of an event. To do so, I conducted an online study to present a collection of photos associated with a set of Meetup events and assess what information users can infer about the events from each photo collection. In the rest of this chapter, I report on the details of our study, and our analysis of what signals participants noticed in the pictures and how they interpreted them. Our results present the importance of cross-boundary objects to transfer reliable signals from the offline world to the online world. The results of our research inform the design of hybrid online-offline communities to achieve their goals of community building and strengthening offline connections.

5.1   Methods

I designed this study as an online questionnaire and conducted it on the online crowd-sourcing system, Amazon MTurk. The study was designed to separate the event pictures from the rest of the information about events to allow us to understand the role the pictures can play in supporting members of online-offline communities. We utilized the existing event photo collections on the Meetup platform. We selected twelve events organized between 2016 until 2017 by public groups in a midsize city in the United States. Overall, the events on Meetup.com can be categorized into three major categories of *Socializing*, *Activity*, and *Technology*. We selected four events in each category of events. To ensure consistency across the events in our study, we ensured that all of the twelve events included at least five and at most 10 photos that were posted after the event and that at least 2 people RSVPed to attend as a confirmation of event happening. I also only included photos publicly available to anyone on the Web to not violate any privacy concerns [1]. The detailed information about each event included in the study is summarized in the Table 4.

There are a few considerations behind the design of this study. I've actually considered and conducted an initial content analysis of 10,586 event pictures on Meetup by utilizing Microsoft Computer Vision API [2] before design this online study. However, I eventually realized the having first-hand data from people is critical to understand what signals can be conveyed by event pictures. While the API can tell what kinds of objects are in the images, I still do not know what kinds of information people who view these pictures can infer as a signal receiver, unless we asked their opinion directly. Moreover, while the API annotates each images and categorizes them into 15 major categories (i.e. such as people, food, outdoor etc.) and 86 sub-categories [3] based on the objects detected in the images, it can hardly identify latent signals such as how comfortable the environment is or how engaged event attendees are. Figure 2 showed the brief results of my initial analysis. Having people and outdoor as the most dominating categories of those photos do not provide much insight

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[1]For the purpose of this paper, we have also blurred any face in the pictures.

[2]https://azure.microsoft.com/en-us/services/cognitive-services/computer-vision/

[3]Full Category Taxonomy: https://docs.microsoft.com/en-us/azure/cognitive-services/computer-vision/category-taxonomy

Table 4: Twelve events selected for the survey study.

Event type	Event title	RSVPs	# of photos
activity	Mt. Lebanon Zentanglers	7	6
activity	You Gotta Regatta: Three Rivers Regatta	10	5
activity	Wednesday Pickup Volleyball	18	7
activity	Fifth annual Halloween game	8	10
socializing	Discuss a Series of Novels by Isabel Allende	8	6
socializing	Celebrate Erick's Birthday at Howl at the Moon	10	8
socializing	Go Wild! Art Exhibition June 24 & 25	2	8
socializing	Ice Cream Crawl!	13	9
technology	Adaptive Families How and Why.	15	7
technology	PYP Talks with Professional Motivator Darren Miller	5	6
technology	Immigrants & Refugee: Inclusive Innovation Week Planning	35	5
technology	javascript class	13	7

about the signals of events. Also, I decided to conduct the study on Amazon Mturk as we can quickly get a relatively large and more representative sample compared to recruiting participants on campus or in local communities.

5.1.1 Survey information

For each event, we presented the participants with the photo collection available for the event. An example of the photo collections for each type of event is presented in Figure 3. As the survey was conducted on MTurk, it was divided to tasks and each respondent had to complete one task. Respondents were informed that each photo collection included photos taken during a local event in an American city. Each task asked the respondent to carefully review the photo collection associated with the task and respond to eight questions.
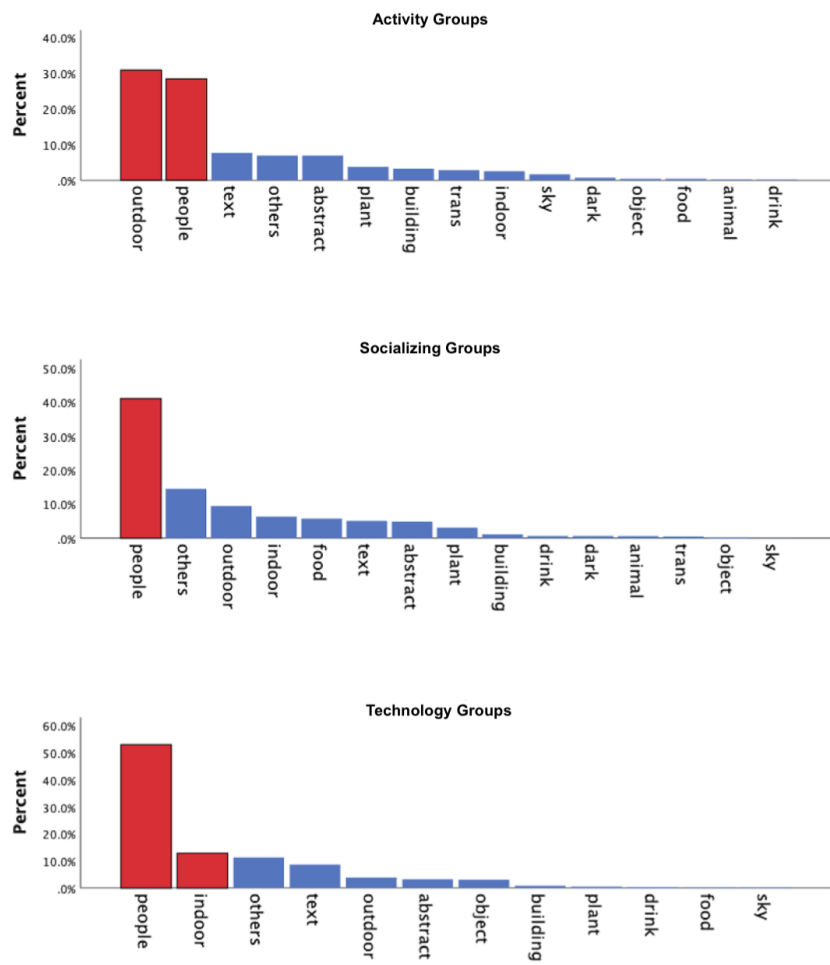
Figure 2: Distribution of major categories based on the results returned by Microsoft API

The questions were focused on four measurements: to what extent participants can judge what the event is about based on the pictures by asking them to identify the topic of the event and to what extent participants find the event engaging, interacting, and enjoyable based on the pictures. Each question was presented as a multiple choice question with always including an option of "I cannot infer this information from the photos". We also included an open-ended question asking participants to provide any additional information they can infer from the pictures. To ensure the reliability of our data, we included a question we asked the participants about the number of people in the collection. Since we had the correct answer to that question, we compared responses against it to exclude any cases of unreliable data.

(a) Socializing Event   (b) Activity Event   (c) Technology Event

Figure 3: Example of photo collections presented to survey participants

5.1.2   Survey participants

We restricted the participants to include only those who are from the US, are over the age of 18, and had a task acceptance rate of at least 99% on Mturk. Due to the exploratory nature of this survey, we decided to set the targeted sample size as 240-260 responses with 6% marginal error, 95% confidence level to the results are representative to the general population (US population = 327.2 million in 2018). As a result, we collected 240 responses in total (20 responses per event). On average, participants spent about 4 minutes to complete the survey and each respondent was paid 20 cents US dollars for their participation. I did not have to exclude any part of the data as we were satisfied with the quality of the entire

data we collected. All the participants passed the qualification test and in response to a question to provide 3 keywords describing the event, they all provided the keywords which were relevant to the event pictures.

5.1.3 Analysis Method

I conducted a mixed method analysis: Quantitatively, I measured at what level respondent were able to judge any of the key factors and how accurate their responses were. For each event, I calculated the number of "cannot infer" options and at what level their responses were correct. Qualitatively, I coded all the free responses in terms of what signals were encoded in them in relation to topic, location, social dynamics, and success of the events.

5.2 Results

In this section, I describe the results of our analysis of the survey responses in relation to each of the signals about events description, social dynamics of the events, and success of the events.

5.2.1 Inferring event description

In case of Meetup.com or similar platforms, each event includes basic description about what the event is about and where the event will happen; however, these event descriptions are often very descriptive and factual and lack individuals perception of what the event is about and what are the characteristics of the event location. The first part of our survey focused on understanding how the photo collection associated with an event can be informative in grasping the overall purpose of the event and the general sense about the whereabouts of the event.

Table 5: Ability to infer event information based on photo collection

	Event Type											
	Activity				Socializing				Technical			
	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
Infer event type	19	18	19	20	20	20	20	18	18	17	17	19
Infer event description correctly	11	18	19	20	20	19	20	9	16	9	6	19
Infer engagement	7	18	20	20	18	20	20	19	20	20	19	20
Infer interactivity	5	18	20	20	19	20	19	19	18	16	20	18
Infer # of attendees	7	18	20	19	20	17	20	16	20	20	20	20
Infer # of RSVPs correctly	3	9	15	16	20	16	16	14	20	20	18	13
Infer enjoyment	5	20	20	20	20	20	20	19	14	14	17	17

5.2.1.1 What the event is about The first part of Table 5 presents participants' responses to question of "What do you think the event is about?" The participants were able to choose between options of "A socializing event", "An activity event", "A technology-focused event", "Other topics", or "I cannot infer the information". The first row of Table 5 present number of respondents (out of total of 20) who were able to infer the event type for each of the 12 events in our survey. Overall, we can observe that for almost all the events, participants perceived the information presented in photo collection sufficient to infer the event type. However, as presented in the second row, not in all cases, they were able to infer that information correctly.

The Activity event which was highly mis-classified, is the "Mt. Lebanon Zentaglers" event and its photo collections represented only art pieces which was created during the event, without any representation of people attending the event or the location of the event. As a result, eight out of the 20 respondents indicated the event as a sale or an arts showcase,

instead of an activity event about creating the arts, as also confirmed through surevey participants' open responses: *Photos are just of a few dozen art pieces and no people or environment. It cannot be inferred from the photos if the art was done during this event or just displayed for the event.*

Similarly, the socializing event which was highly mis-classified, is the "Ice cream Craw!" event with photos only representing the ice cream shop and did not include much information about individuals attending the event. As a result, a large number of our survey respondents categorized the event as *"Ice cream shop opening"* or *"People eating at an ice cream shop"* rather than an ice cream crawl social gathering. For the Technical events a large number of our survey respondents had selected "Other" or "Activity" event types rather than technology-related event as many of the pictures only represented a general speaker event or a workshop.

Additionally, participants' responses to the survey open-ended question revealed how our participants can infer further detailed information about the events; such as, what specific topic was covered in a Technology event or where specifically an activity event had happened, or what the purpose of a social gathering had been, as highlighted in the quotes below:

> **Inferring the nature of the event**: *It looks like a group of people were at a workshop learning about some software that can create 3D models.*
> Or
> *People were out at a bar celebrating Eric's birthday.*
>
> **Inferring type and location of the event from objects and people in the picture, and surroundings**:*The Ferris wheel, large crowd in the back indicates maybe a music festival, a historic landmarks of a particular state or city.*

5.2.1.2 Whereabouts of the event

In addition to the topic of the event, the open-ended responses from our survey participants highlighted how the pictures can be utilized to infer information about the location of the event.

> **Objects in the picture prompting the type of events**:*The dueling pianos draw my attention to the type of venue this event was hosted at.*
>
> **Inferring the size of the event**:*Seems to be slightly small for a birthday party.*
>
> **Inferring the appeal of location**:*A nice volley ball court surrounded by a beautiful green landscape.*

Or

The classroom setting for this event is strange, it's narrow and long, and doesn't appear to have been originally designed to be a classroom.

While I did not reveal the name of the city in the survey questionnaire, there were a few respondents who recognized the city based on the surroundings in the photos. For instance, a respondent described *"Since I have been to [city name] many times, I recognize the fountain on the point in downtown.* In addition, they also inferred the season of when the event happened, *"Since the people in the photos are wearing shorts, this event most likely took place during the summer."*

We found that people use the information about the event environment to get a sense of where and when the event was happening, who had been there and what are the characteristics of the location. For instance, a respondent viewed the photo collection of the socializing book club event, and wrote *"The table decorations are simple as to not draw attention from the food. It doesn't look like this has been put together for a large group. It seems like it has been organized for immediate family."* Similarly, in another comment *"I notice that there are framed pictures in each photo. These pictures have a small sign under them making me think that some of the people in the photo are their artists.*

Furthermore, we found that if there are multiple venues shown in the photo collections, respondents were able to imply the set of activities during the event time.

Indicating a series of activities within the event: *"A group of people is playing frisbee in the daytime. Some seem to be in costume for Halloween. They seem to have gone to a restaurant together afterwards."*
Indicating more than one activity within the event: *"there are a few different events going on at one event as there are different background shown in the photos'*

5.2.2 Inferring social dynamics of the event

The next set of questions were designed to assess at what level pictures can communicate more implicit aspects of events that are often difficult to capture and represent online. These questions asked the survey participants, "To what extent do you agree or disagree that people were truly engaged in this event", and "To what extent do you agree or disagree that people were interacting with each other during this event". Respondents were able to choose among

7-point likert scale options ranging from strong agreement to strong disagreement or they could select the option of "I cannot infer that from the photos". On average, across all 12 events, 18 out of 20 respondents perceived the pictures sufficient to infer the level of engagement and level of interactivity. Similar to previous results, *Activity 1 Event* that its pictures did not include any person, scored significantly lower than other events in terms of how many of the respondents found the pictures enough to infer the acquired information. Since we have no ground truth about the actual level of engagement, and interactivity, we cannot judge whether the survey respondents inferred the information correctly or not. Therefore, to get a sense of quality of their responses, we calculated the agreement among participants on these measures. We assume that high agreement is an indication that the pictures were informative enough for our survey respondents and they could independently arrive at the same decision about engagement and interactivity. Our results shows the average inter-rater agreement for engagement is 0.88 and for interactive is .72. In both cases the results suggests a very high inter-rater agreement suggesting the survey participants were able to arrive at a similar decisions based on the pictures. Furthermore, the open-ended responses represent a very strong indication that respondents further highlighted how the pictures enabled them to identify level of engagement and interactivity, as highlighted below:

Indicating high engagement: *"Everyone was drawn to the boards and writing on note"*

Indicating low engagement: *"The overall attitude of the people sitting at tables seems to be one of disinterest and boredom."*

Indicating high interactivity: *"It looks like a group of people working together to organize information or plan something together.*

5.2.3 Inferring success of the events

The ability to get a sense of participation in an offline event through the pictures can serve as an indication of the popularity of the event and can compensate inaccuracies of online RSVPs as in many cases individuals might RSVP online but not actually attend the event or those who have not RSVPed to show up for the event. The next set of our questions focused on assessing at what level respondents could judge the success of the event in terms

of how many people had attended the event and at what level the events participants were enjoying the event.

In terms of number of attendees, across all 12 events, on average 18 out of 20 respondents were able to infer the range of how many people attended each event. Further, 15 out of 20 respondents estimated the range of number of participants correctly, compared to the actual RSVPs number on the Meetup.com site. As presented in Table 5, for the first two Activity events, there are much fewer responses and correct responses. As mentioned in the previous section, photos associated with the *Activity 1 Event* do not include any people in them which makes it difficult to draw any conclusion about number of people attending the events. For *Activity 2 Event*, the associated pictures included a large number of people in the background which caused majority of our participants to over-estimate the number of event attendees. Responses to the open-ended survey question show that the survey participants infer the number of participants not only from the people in the pictures but also through other aspects of the scenes, as highlighted in the quotes below:

> **Indicating number of people based on objects in the picture**: *I notice there are more cups than people, indicating there may be additional people not pictured.*
> Or
> *The table decorations are simple as to not take away attention from the food. It doesn't look like this has been put together for a large group. It seems like it has been organized for immediate family.*

Moreover, the survey respondents were able to infer additional information about the participants of the events beyond just their numbers, including demographic information such as the age, gender or race as well as relationships between attendees, such as whether the event participants are family members, friends, work partners or strangers, as highlighted in these quotes: *"There were people of all ages in attendance.", "Just white people in the photos.", "It is an all female event."* and *"This event or what the images show seems to be dominated by a mostly male presence.", "all five individuals are huddled close together, indicating a close ties and/or bonded by a shared interest"*. We also found the outfits of attendees in the pictures helped our respondents to infer more information about the events. For instance, *"It appears that some people really tried to dress up for the event so it could be a pretty formal one.* or *"All the plastic cups, the dog, and the man with the guitar makes*

me think this is a casual party for an art club."

In terms of level of enjoyment, 17 out of 20 respondents were able to infer that and their average inter-rater agreement was .78 (SD=.26). They further highlighted their inference of enjoyment through open responses such as *"nice weather, people having fun and playing together."* or *"The artist, musician, and supports seem very proud, and happy to be at this event."*

5.3 Discussion

In this Chapter, I presented a study of the role of Meetup events pictures to reduce information asymmetry between online and offline spaces of hybrid communities. I conducted an online study to assess how content of the pictures can serve as signals of offline events for those who have not attended the events. Our results show that pictures embed rich information about the events. The large majority of our participants were able to infer information about "what the event is about and whereabouts of the event", "social dynamics of the event", "how many people and what kind of people attended the event", "how the event went". Below, I discuss the key themes in our findings and the design implications of our study.

People are important signals. Across all the measures, the "Mt. Lebanon Zentaglers" event received significantly lower number of correct responses. A unique feature of the pictures of that event is lack of representation of people in the pictures. The rest of cues embedded in the pictures were found insufficient by our respondents to infer the key information. We observed that presence of people in the pictures is one of most important signals that can be used to convey a variety of information about the event. Beyond the obvious information about the number of people shown in the picture as indicator of how many people attended the event, presence of people can signal additional information such as demographic diversity of the event, the social norm of the event, the relationship between the attendees, and the social dynamic of the event. This finding aligns with the results of research in the field of contextual image recognition and analysis. For instance, Gallagher

and Chen [25] found that the social context in the picture of a group of people such as the positions and distance between human faces can be reliably utilized to automatically recognize event type (i.e. dining events).

Pictures are reliable signals. Information embedded in pictures can be difficult to fake which makes them a very reliable signal. The results of our study showed that, comparing to event description available to us as ground truth, people were able to infer quite accurately "what the event is about" and "where the event is happening" with merely viewing the event pictures. Our result demonstrate that not only the event pictures can be informative in providing a quick preview about event description but also authentic and implicit signals about the events quality such as attractiveness of the locations of events, or how engaging, interactive and enjoyable the events are. Not only such information often is not provided in textual format by the event host or other attendees, even if it is provided, its authenticity and credibility can be questioned by users. This is in alignment with prior research which also suggests that online photo sharing practices are a reliable reflections of what happens offline. For example, a quantitative study on Instagram [75] showed that photo sharing pattern is a good indicator of cultural behaviors, and can help to identify the vibe of *Place of Interests* and to detect local events.

Signals embedded in pictures are intuitive and attractive to people. Amazon Mechanical Turk has been widely used as crowd-sourcing platform for assigning human computation tasks such as extracting data from images, audio transcription, and content classification [55]. However, the tasks we assigned to our respondents in this study is not trivial and required them to carefully view the photo collections of an event and specifically provide open-end responses about what they noticed in the pictures. The volume and quality of these optional open-ended responses is at high end of expectations of MTurk studies. Not only all our 240 respondents were fully engaged to correctly answer the qualification question, 234 (97.5%) of them provided the optional open-ended response with additional information they inferred about the event (included a average of 16 words). More importantly, they shared very meaningful insights about the different aspects of the events, such as the nature of the activity, the location, or participants information, much of that in an unprompted nature. These results presents that not only pictures embed rich information, the task of

interpreting pictures is intuitive and attractive to people and does not pose undesirable cognitive load on them. Further, we observed a very high inter-rater agreement among our participants in judging the level of engagement, interactivity, and joyfulness of events. This is another indication of high quality of data collected through the study tasks. To ensure high quality responses, in design of our study, we followed the MTurk quality assurance guidelines in the literature; however we also consider such unusually high quality responses to be the result of how our study task is engaging by nature. Extracting social signals from images seems to be an intrinsically engaging task.

In summary, the results of this study demonstrated the opportunities to utilize event pictures to convey reliable signals about offline happenings back to the online platform to assist those who did not attend the event in better understanding of offline events. However, it remains unclear that whether and how those signals conveyed by cross-boundary artifacts about what happened in the past events help people to make the decisions of participating in future events in the same group. In particular, what characteristics of such artifacts impact the decision making process and how we can design and utilize those artifacts in hybrid communities that ultimately reduce information asymmetry and support members who did not have experience with offline activities to select offline events that meet their needs and expectations.

6.0 The Impact of Cross-Boundary Artifacts on Offline Participation

The overall goal of my dissertation work is to investigate how cross-boundary artifacts can be utilized and designed as an effective mechanism to support hybrid communities in reducing the information asymmetry and therefore facilitate participation of members. In Chapter 5, we've learned that cross-boundary artifacts can serve as signals that communicate information about offline events in hybrid communities for those who have not attended the event. In this study, I aim to further understand how different characteristics of such artifacts influence their decisions of attending upcoming events in the group. In order to examine the casual relationships, I designed the study as a lab controlled experiment and each participant were recruited to attend a 45-minutes in-person session.

In hybrid communities like Meetup groups, there are two common formats of cross-boundary artifacts - *visual* and *textual*. Pictures are visual artifacts that capture offline happenings in the moment during event time and communicate signals of such events when shared in the online space afterwards. Comments are lightweight textual artifacts that allow people who attended the past event to write and share information about such event in the online space. Our results in Chapter 5 showed that pictures can serve as reliable signals to convey information of offline events. Comments, on the other hand, is a more widely used artifacts in Meetup groups compared to pictures. In our dataset, only 4% of events have photos but at least one comment was posted for 34% of events and 32% of those comments were posted after the event time. Comments can be a good artifacts that allow attendees to more easily express and share their personal opinions and perspective of the event. In this study, I am interested to learn if the old saying "A picture is worth a thousand words" holds true in the comparison between the effect of visual and textual cross-boundary artifacts in hybrid communities. Furthermore, I aim to understand the advantages and disadvantages of these two formats respectively, in terms of reducing information asymmetry and support participation.

Another important factor that can impact the effect of cross-boundary artifacts on people's decision of an upcoming event is the quantity of such artifacts. According to signaling

theory, the reliability and credibility of signals serve as critical factors that influence how receivers interpret the information [16]. Research in the field of e-commerce has revealed that quantity of reviews of a product influences the purchase intentions of consumers [64], and predicts the sales of products [17, 49] as the high quantity of reviews can be perceived as a strong reliable signal of quality in the word-of-mouth phenomenon. In the context of hybrid communities, I hypothesize that the more cross-boundary artifacts of the past events presented in hybrid communities, the more likely people feel they receive reliable signal to assess the quality of those events and hence support their decision making process of attending future events.

In addition to format and quantity, signaling theory suggests that the strength of signals is also essential for receivers to assess the quality of the situation. In the context of hybrid communities, the strength of signals about offline happenings communicated by cross-boundary artifacts can influence how receivers (i.e. members in the online space) make judgments on the quality of past events hosted in the groups and therefore impact their decision about attending future events. Our results in Chapter 5 showed that people were able to infer information about how interactive, engaging, and enjoyable the past event was. As stated by event organizers in our interview study (in Chapter 4), those information about offline interaction was considered as the key information that represents the quality and success of events. Therefore, I hypothesize that more information that allow members to assess the quality of past event, the more likely they will be confident in making decisions about future events.

The goal of this work is to investigate how those key characteristics of cross-boundary artifacts, including (1) *Format*; (2)*Quantity* and (3) *Signal strength of offline interactions*, impact receivers' decision making process. To summarize, I aim to answer the following research questions:

1. Whether and how does the **format** of cross-boundary artifacts which represent offline activities in past events impact receivers' decision in attending future events? What are the advantages and disadvantages of the visual and textual formats respectively, if any, in terms of reducing information asymmetry and support participation?

2. Whether and how does **quantity** of cross-boundary artifacts influence to receivers' de-

cision making process?

3. Whether and how does the **strength of signals representing offline interactions** communicated by cross-boundary artifacts impact the decision of receivers in attending future events?

In the rest of this chapter, I start with describing the design of our study, and then present our analysis to examine the effect of different characteristics of cross-boundary artifacts on participants' decision making process. At last, I discuss the important lessons I learned from this study. Our results inform utilization and design of cross-boundary artifacts in hybrid communities to best support decision making process of members as well as facilitate successful offline events.

6.1 Methods

I designed this study as a controlled lab experiment. I recruited twenty participants and every one of them was invited to attend a 45-minute session in our research lab. The main purpose of this study is to investigate whether and how cross-boundary artifacts of past events in hybrid communities help people who have no prior experience in the group make their decision of attending upcoming events in the group. In this section, I present details of my study design, the process of data preparation and interface design as well as our participant recruitment and analysis method.

6.1.1 Study design: Independent Factors and Outcome Measures

The basic idea of this experiment is that participants were shown information of upcoming events with cross-boundary artifacts and they were informed that those artifacts were shared by organizers or attendees of previous events hosted in the same group. As outcome measures, each participant was asked to rate (1) the likelihood of attending each upcoming event and (2) the level of confidence for participants to make such decisions. As described early, I manipulated on three key characteristics of cross-boundary artifacts in this study, including

Table 6: Operationalization of three characteristics of cross-boundary artifacts with different conditions in the experiment

| | | Format | |
		Visual	Textual
Quantity	**High**	12 pictures per event	5 comments per event
	Low	3 pictures per event	1 comments per event
Signal Strength of Offline Interactions	**Strong**	At least two people in each picture	Incl. details about offline interactions
	Weak	One person in each picture	No details about offline interactions
	None	No people in each picture	

(1) *Format*; (2)*Quantity* and (3) *Signal strength of offline interactions*. I defined different levels of the three factors in this experiment. In terms of format, I included both visual (event pictures) and textual artifacts (comments). To test the effect of quantity, I controlled the number of artifacts associated with upcoming events in two levels: *High* and *Low*. For the strength of signals about offline interactions, there are three levels included in the test: *Strong*, *Weak* and *None*. As shown in Table 6, I operationalized each characteristics with different levels. The quantity level of visual and textual artifacts were decided based on the statistics of our two-year dataset of Meetup groups[1]. For comments, the strength of signals communicating offline interactions was determined as *Strong* or *Weak* based on whether or not details about offline interactions were described. In the context of Meetup, we can hardly find comments posted after event time without mentioning the offline event at all. Hence, I exclude the condition of "no signal of offline interactions" for comments, considering that

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[1]For events with pictures, 75th percentile and 25th percentile of the number of pictures in our dataset are 12 and 3, respectively. For events with comments, 75th percentile and 25th percentile of the number of comments are 5 and 1.

as long as there is a comment, viewers can infer certain level of offline activities happened during the event. On the other hand, our results in Chapter 5 indicate that the presence of people in the picture is an important signal that help receivers to infer a variety of key information to assess quality of events, including the number of attendees, social dynamics, demographic and relationships between attendees in offline activities. I used the number of people presented in the picture as a proxy for the signal strength of offline interactions. Pictures with more than one persons were likely to directly communicate strong signals about offline interactions among attendees. Pictures with only one person can still convey weak signals about offline activities since viewers can still imply that a group of people got together in the physical world if there are multiple pictures for an event. However, pictures without any person can seldom communicate offline interactions among people. Figure 4 present examples of cross-boundary artifacts corresponding to different signal strength and formats for a hiking event. Given the number of factors (3) and number of levels (2 or 3) controlled in this experiment, we can have up to 10 condition groups. However, I decided to include seven conditions in this study since I am not necessarily interested in the second degree interaction effect of the three factors. Table 7 summarized the seven conditions of this study as the combination of different levels in the three factors of interests. These seven conditions allow me to examine the effect of the three factors in isolation.

6.1.2   Procedure of the experiment

This study was designed as a within-subject experiment in order to limit the number of participants I need. Every participant was asked to complete 15 tasks. In each task, participants were shown an upcoming event and informed that the event was hosted by local groups in the city of Pittsburgh. Similar to the study in Chapter 5, I show five events from each of the three event categories (*Socializing*, *Activity*, and *Technology*) to each participant. The order of the five events within each category as well as the order of the three categories are both randomized. For each event, basic information including title, description and the name of the group and people who organized the event was presented on the event page. Figure 5 presents an example of event page showed to participants in the experiment. Participants

(a) Comment with strong signal of offline interactions

(b) Comment with weak signal of offline interactions

(c) Picture with strong signal of offline interactions

(d) Picture with weak signal of offline interactions

(e) Picture with no signal of offline interactions

Figure 4: Example of cross-boundary artifacts with different formats and signal strength of offline interactions for a hiking event.

were asked to answer the following two questions after reading the basic information about each event:

- *On a scale from 0 to 10, how likely are you to attend this event? ("0" for "not at all likely and "10" for extremely likely)*

- *On a scale from 0 to 10, how confident are you in your decision to be satisfied with this event if you attend it? ("0" for "not at all confident and "10" for extremely confident)*

Then, the section of cross-boundary artifacts from prior similar events in the same group

Event title:

Hands-on day workshop on Big Data Hadoop Projects

Description:

Learning about big data and analytics can help you gain a competitive advantage in your own career. Hands on experience on big data Hadoop projects will also make you understand the theoretical concepts even better. Attending this one-day workshop, you will gain extensive knowledge on Big Data Hadoop projects which can enhance your career. Anyone who are interested in working on live project in Big Data Hadoop to accelerate your career with hands-on experience are perfect participant for this one-day workshop.

Hosted by: Carson

From: Pittsburgh Data Science

Figure 5: An example of event page of a Technology event with basic information showed to participants in the experiment

Table 7: Seven conditions in the experiment

Condition	Format	Quantity	Signal Strength of Offline interactions	Num. of responses
1	Picture	Low	Strong	44
2	Picture	Low	Weak	44
3	Picture	Low	None	42
4	Picture	High	Strong	43
5	Comment	low	Strong	41
6	Comment	High	Strong	43
7	Comment	High	Weak	43

were shown to participants in addition to the basic event information. For every participant, the condition of cross-boundary artifacts associated with every one of the five events within the same category was randomly selected from the seven conditions in Table 7 without repetition. The last column in the table shows the number of responses I collected during the experiments for each condition. After viewing the cross-boundary artifacts presented on the event page, each participant was asked to answer the same two questions as above **again**. Participants were also required to explain their decisions verbally for each event throughout the experiment. At last, they need to complete a short questionnaire for basic demographic information including age and occupation. They were also encouraged to share previous experience in in hybrid communities and opinions towards cross-boundary artifacts.

6.1.3 Event Material Preparation

In this experiment, all the information about the upcoming events were artificial and mimicked based on the data from Meetup.com. I intentionally decided to compose artificial event information instead of using real data from Meetup.com to keep events in the experiment consistent. In particular, I attempted to keep the topics and description of the five

events within same category as similar as possible. Therefore, I can minimize the potential influence of confounding factors (i.e. topic of activity, description of venue, etc.) on participants' decision. Then, our results can be valid to explain the effect of the characteristics of cross-boundary artifacts presented on the event page. I also excluded the information about time and location for all the events and asked participants to assume that the time of the event work for them and the venue is accessible while making their decision about attending events.

I prepared ten events in each category and every five events comprise a subgroup around a same topic. Every participant was allowed to select one topic within each category based on their preference. Table 8 lists the title and topic of all the events included in this study. All the event pages with event information and cross-boundary artifacts as well as the questions of likelihood and confidence level of attending the events were programmed in Qualtrics [2]. Figure 6 presents the artificial information of three events in the topic of "Lunch Meetup" to illustrate the similarity between event description to minimize the potential impact of confounding factors in the experiment.

6.1.4 Participants

I recruited 20 participants by posting physical flyers in the neighborhood of our research lab. Participants were required to be at least 18 years old and capable to speak and read English frequently. Each participant completes 15 task during the experiment so I collected 300 responses in total. Our responses were almost evenly distributed across different conditions in the experiment due to the randomization in our design (as shown in Table 7). Each participant was compensated by 15 US dollars for their participation. Our sample is relatively balanced in gender - 12 out of 20 participants are female; however, 19 of our participants are below 35 years old[3]. Each experiment session lasts for about 45 minutes. All the answers regarding participants' decision and confidence level of attending each events were automatically recorded by Qualtrics. All conversations during the experiment were audio recorded as well as transcribed.

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[2]https://www.qualtrics.com/

[3]There is no public data about the age distribution for users of Meetup.com

Table 8: Collections of events in the experiment

Category	Topic	Event title
Socializing	Happy hour	September happy hour
		Happy hour on Friday
		Happy hour party at Thunder Brewers
		Fall happy hours
		Weekend happy hour
	Lunch Meetup	Brunch on Sunday
		Lunch at Monarch
		Lunch at a newly opened restaurant
		Lunch at The Paradise Dome
		Lunch at The Modern Peasant
Activity	Hiking	Hike in North Cascades
		Hike to Talapus Lake
		Hike in Clark's Creek Park
		Naches Peak Loop Hiking
		Hike at Lake Ingalls
	Biking	Riding together
		Biking in Talapus Lake Park
		Biking in Clark's Creek Park
		Naches Peak Loop Biking
		Biking at Lake Ingalls
Technology	3D printing workshop	3D Printing Workshop at Global Homestead Garage
		3D Printing Meetup in Pittsburgh
		3D Printing Meetup: from photo to 3D
		3D Printing Meetup coming soon!
		Pittsburgh 3D Print Workshop
	Big data workshop	Big Data Workshop
		Workshop: Big Data (Kafka)
		One-day Workshop on Big Data & Hadoop
		Big Data Hadoop Hands-on Workshop
		Hands-on day workshop on Big Data Hadoop Projects

6.1.5 Analysis Method

To gain a comprehensive understanding of the impact of cross-boundary artifacts on participants' decision making process, I conducted both qualitative and quantitative analysis using the data collected from the lab experiments. Qualitatively, I analyzed the verbal explanations participants provided during the experiment in terms of why they made certain
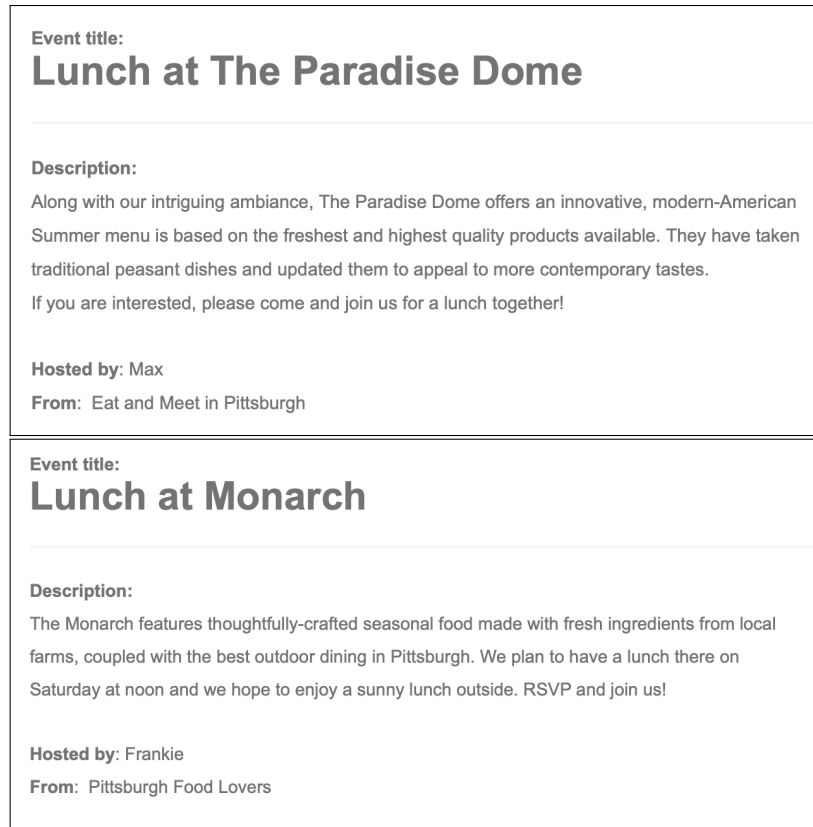
Figure 6: Examples to illustrate the similarity between event description under a same topic (Lunch Meetup)

decision for each event in relation to the characteristics of the cross-boundary artifacts. Quantitatively, I run a series of linear regressions. The independent variables include the format, quantity and signal strength about offline interactions of cross-boundary artifacts. As outcome measures, I focused on the **change** of two metrics (likelihood of attending upcoming events and the confidence level of decisions) **after** viewing cross-boundary artifacts associated with the event compared to their answers **before**.

6.2 Results

Below, I describe the detailed results of this experiment focusing on the impact of cross-boundary artifacts regarding to different formats, quantity and offline interactions.

6.2.1 Cross-boundary artifacts reduce uncertainty of upcoming events

The results of this study highlighted the relationship between the effect of cross-boundary artifacts and the level of uncertainty people have about an event. I found that the more uncertain people are in terms of what to expect when attending an event, the larger impact of cross-boundary artifacts on supporting the decision making process since such artifacts help to reduce people's uncertainty about the events. Participants reported that they feel pictures and comments are useful for making the decision of attending an event only if they provide new piece of information in addition to the event description and their own prior experience in similar events, as stated by the following quotes from participants.

> *These photos do not add anything new. It's like what I assumed - I know a social event would be meeting a lot people but It would be much useful if they show pictures about the food and the environment.*
> OR
> *I think the only thing that I was not sure about it after reading the description was the view. But reading these comments, I got that information, it says "the trail was really beautiful and it's good for beginners." I'm now more confident that I will enjoy it.*

Our quantitative analysis also showed that the less confident participants were about their decision of attending an event before viewing cross-boundary artifacts, the larger the effect of viewing such artifacts on increasing confidence level afterwards. Controlling for artifacts quantity, signal strength about offline interactions and event category, one unit decrease of the confidence level before viewing comments of previous events results in 0.3 more units increase in the change of confidence level afterwards (as shown in Table 9. For artifacts in the format of picture, even though I did not observe statistically significant impact of quantity and signal strength about offline interactions on confidence level change, the level of prior confidence level significantly influences the change of confidence after viewing pictures of past events (Coef. = -0.31, SE = 0.062, Wald χ^2 = 25.21, Sig. <0.001).

6.2.2 Quantity of artifacts is sensitive for comments but not for pictures

I found that the quantity of artifacts is sensitive for comments but not for pictures. The significant factors of the analysis are presented in Table 9. Specifically, participants who viewed five comments from past similar events increased their likelihood of attending the upcoming events 6.5% more than participants who viewed one comment[4]. Similarly, viewing five comments results in 6% more increments of participants' confidence in making their decisions, compared to viewing one comment. However, there is no significant difference in the change of likelihood nor confidence in attending events between viewing 12 and 3 pictures of past similar events.

Table 9: Impact of the artifacts quantity and signal strength of offline interactions for comments

Outcome Variable: Change of Confidence Level				
Parameter	Coef.	SE	Wald χ^2	Sig.
High quantity	0.59	0.228	6.75	0.009
Strong signal strength of offline interactions	0.60	0.252	5.63	0.018
Prior-confidence	-0.31	0.114	7.50	0.006
Outcome Variable: Change of Likelihood of Attending Events				
Parameter	Coef.	SE	Wald χ^2	Sig.
High quantity	0.65	0.283	5.21	0.022
Strong signal strength of offline interactions	0.58	0.262	4.81	0.028

Our qualitative data provide more evidence and reasons for these observations. None of our 20 participants mentioned about how 12 pictures is different than 3 pictures in making their decisions. However, one comment was often considered as less useful than five comments

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[4]To better interpret the results, I convert the scale of (1) the likelihood of attending events and (2) their confidence of making the decision from (0 to 10) to (0% to 100%).

for the following two reasons. First of all, participants feel that one comment does not provide reliable information for them to make confident decision, as highlighted in the quotes below:

It's like a review on Amazon, I would look for opinions from different people. Only one comment make me doubt about how reliable it is
OR
In general, the more (comments) the better. You can trust more if they are coming from different people.

Moreover, only one comment can lead negatively influence people's assessment of the success of past event organized in the group.

There's only one comment, I don't know how many people went to the event. But it kinds of giving me the signal that this event may not be popular. I wonder if anyone will go there.
OR
Since it is only one comment for this event, it seems that very few people likes events in this group.
OR
I doubt how well the event went since there was only one comment.

In contrast, people found photos convey more objective and trustful information than comments.

I like this event that has photos. Compared to comments, photos are more objective. To me, comments can be too personal that I may feel differently than someone else, but photos cannot lie.

6.2.3 The goals of potential attendees affect what signals they seek

Our results suggested that what kinds of signals is effective depends on the major goals people want to achieve by attending offline events.

Seeking for signals about social interactions. As an example, people reported that signals about social interactions are important while making decisions about attending socializing events.

If it is a social event, I don't see people enjoy themselves, talking with each other or I don't see people at all it's wired. 'cause social events are mostly between people. If you just show a random bar with no people in there, that's weird because I'm not seeing what kind of things you are doing.
OR
These pictures (with single person) did not seem reflect the group sense, so it does not affect my decision.

The presence of people is less important when people's goal is to experience the activity. Compared to socializing events, more people tend to seek for signals about natures and views to assess the quality of Activity events. I learned that people's primary goal was doing the activity so the environment and logistics which determine the quality of the experience are more critical. Therefore, the presence of people is less important in terms of supporting their decision making process.

> *I know before I said if there is no people I don't believe it (for socializing events) but this is different because **I'm not going there for people anymore. I'm going here for the nature.** So the kind of place they pick are kind of nice. Especially this one, I like water a lot. This bridge is cool. I feel these guys have actual stuff so I will definitely like it.*
> OR
> *I don't know what kinds of place they will go. **I think places matters the most in hiking** - whether it's suitable for beginners. But they did not give me that kinds of information (with group photos).*

People look for group interactions and environment if their goals are collaboration and teamwork. In addition, if people's goals are collaboration and teamwork such as attending a hackthon event, they often seek for signals about group dynamics and the environment, as highlighted by the quotes below.

> *I like the photos where people were doing it like a workshop, they worked together in small teams.*
> OR
> *I like the place is clean and neat so I think I will be more likely to pick this event over the other one. I like to work in a well-organized place and it feels like they are professional.*
> OR
> *These photos (with signal person presented) are more confusing. Is this going to be individual work or team work?*

6.3   Summary of Other Quantitative Results

In addition to the results above, I also conducted a few more linear regressions to examine the impact of format and offline interaction representation in cross-boundary artifacts. Specifically, I conducted two linear regressions with repeated measures to examine the impact of the format of cross-boundary artifacts. I did not observed any significant difference

between pictures and comments in terms of their impact on the likelihood of attending events nor the confidence of making decisions. I controlled the event category and the confidence level prior to viewing such artifacts in the regression models. While participants reported pictures generally convey more objective and reliable signals than comments, the relative small sample size of this study did not allow us to observe statistical significant impact of the format and cross-boundary artifacts.

Similarly, I examined if the level of representation of offline interactions influence the effect of pictures and comments in attracting attendance and increasing confidence. As shown in Table 9, our results showed that comments should contain more details to describe interactions among group while the needs for pictures can be more complex. Viewing comments with details about offline interactions of past events in the group results in 5.8% more increments in the likelihood of attending upcoming an upcoming event, compared to viewing comments without details about offline interactions. Moreover, I observed 5.9% more increments in the confidence of participants in making their decision when showing comments of past event with strong signals of offline interactions than presenting comments with weak signals. On the other hand, I did not observe any statistically significant impact of the strength of signals about offline interactions for pictures. Our hypothesis was that the more people presented in the pictures, the stronger signals about offline interactions conveyed; therefore, it is more easily for people to assess the quality of past events and make decisions about future events. However, this hypothesis was not supported by our results. As I discussed in the previous section, our qualitative results suggested that whether the representation of people or group shown in the picture is influential really depends on the primary goal of potential attendees. If they are looking for social interactions or group interactions, people are important; however, if they are interested in the nature or environment, people is not the key signal they are looking for. Our sample size does not really allow us to run separate analysis based on reported goals of participants, thus future studies are needed to provide more quantitative evidence for our findings.

6.4 Discussion

In this chapter, I presented a study to investigate the impact of cross-boundary artifacts on supporting people who have no prior experience in participating in offline activities in hybrid communities. I conducted a controlled lab experiment to examine how the three key characteristics of cross-boundary artifacts, including *Format*, *Quantity* and *Signal strength of offline interactions*, impact people' decision making process. Our results showed that cross-boundary artifacts conveying signals about previous events in the group are effective to reduce people's uncertainty about upcoming events. While the format of cross-boundary artifacts does not significantly impact the effect of such artifacts, we need to consider designing visual and textual artifacts differently to maximize their impact on supporting decision making. The quantity and signal strength of offline interactions positively influence the effect of comments on increasing the confidence and likelihood of people to attend future events. However, the factors that contribute to the effect of visual artifacts on those two outcome measures can be more complex. More pictures is not necessarily more effective in supporting people's decision making process; instead, matching the kinds of signals that conveyed by pictures with the goals people desire to achieve by attending such events is vital. Below, I discuss the key themes merged from our findings along with the design implications.

Reliability of signals can be achieved by either quantity or format of artifacts. The results of this study indicated the importance of the reliability of signals conveyed by cross-boundary artifacts as it influence the effectiveness of such artifacts. As I hypothesized, the quantity of comments were perceived as an indicator of signal reliability in assessing the quality of past events. Participants expressed their concerns about the accuracy and reliability of comment from only one previous attendee. This finding is in alignment with prior research in the field of e-commerce [17, 64]. However, the quantity of pictures did not significantly influence the effect of such artifacts while controlling other factors. It is possible that people trust the signals conveyed by pictures due to its format and thus the quantity of such artifacts does not necessarily add additional value for people to assess the reliability of signals. As I discussed in Chapter 5, information embedded in pictures can be difficult to fake which makes them a very reliable signal. Participants in our experiments also

explicitly commented that the pictures convey more trustful and less subjective information than comments, *"People's feelings may be different from each other, so they like it or not does not mean that I will experience the same. In this sense, photo will be more trustful than personal opinions."*. Our results suggested that pictures are considered as a better format of artifacts to communicate more reliable signals about offline happenings compared to comments; however, we can design textual artifacts to also convey reliable signals if we increase the amount of artifacts associated with an event.

Cross-boundary artifacts have limits on changing decisions. Our results suggested that cross-boundary artifacts are more effective in terms of helping people who were less confident about whether or not attending an event become more confident about their decision. This finding aligns with the results of research in the field of e-commerce. Researchers found that when there is less direct product information available online, the quality of a website as external signals will have a greater, positive effect on consumer perceptions of product quality [78]. I also observed a limit for that effect of cross-boundary artifacts on influencing people's decisions of whether or not to attend offline events. Such artifacts are helpful when people are interested in the event but need more information to assess the quality of such event. Yet, cross-boundary artifacts may not be effective in case that people have little interests in the event. For instance, a participant in this experiment explained by she was not going to change her decision after viewing either pictures or comments of similar events: *"I generally don't like this type of [socializing] events at all so seeing these photos and comments will not change my idea"*. In this case, the participant is not interested in attending socializing events at all therefore she did not feel more likely to attend an socializing event no matter what signals were carried by photos and comments. This finding help to justify that the primary role of cross-boundary artifacts is to reduce information asymmetry and help people to be more confident when considering attending an event they are interested in, rather than convincing people who have no interest in the event at all to change their decisions.

Signals representing social dynamics and event attendance can be insufficient. Our results in Chapter 4 showed that the quality of offline interactions is the key factor to assess the success of events. Providing an engaging, interactive and enjoyable offline experience

is the primary metric for event organizers to consider their events as successful. Further, results of the online study in Chapter 5 demonstrated that people can infer reliable signals from event pictures regarding the social dynamics and event success if there are people presented in those pictures. I hypothesized that communicating signals about offline interactions were by cross-boundary artifacts can attract future participation. I believed that the presence of people in pictures indicates both social dynamics and the level of attendance of the events. I didn't manipulate other signals such as venue and environment and information about participants shown in Study 2 (Chapter 5) for following reasons. First of all, information such as venue and environment are highly determined by the nature of events (i.e. where is the event) and hard to manipulate by cross-boundary artifacts. Also, those signals are less in control and less related to the technical aspects of hybrid socio-technical systems which is the focus of my dissertation. In addition, I need to limit the number of variables in the experiment due to our sample size. Therefore, I decided to focus on offline interactions as the kinds of signals I manipulate in this study.

However, the results of this experiment suggested that signals about social dynamics and event attendance may not be sufficient to support people's decision making process. Potential attendees can have different expectations than event organizers for an event and therefore seek for other signals to assess if their goals can be achieved by attending this event. For instance, organizers of socializing events expect their events to help people connect with each other but attendees of such events also expect to enjoy the food and environment of the venue. In this case, presenting signals about how people socialized with each other in the past events may not be sufficient to attract attendance of future events; instead, conveying signals about the quality of food and environment of the venue can be helpful too. Thus, understanding what are the primary goals of attendees to participate in certain events and designing cross-boundary artifacts that convey signals that meet their goals are essential to maximize the effect of such artifacts.

The results of this study, along with findings in the previous chapters, demonstrated the opportunities to design and utilize cross-boundary artifacts to convey reliable signals about offline happenings back to the online platform and further to support those who did not attend the event to make decisions of attending future events. In the next chapter, I

summarize the key lessons I learned from Chapter 4, 5 and 6 and also discuss guidelines to design and utilize cross-boundary artifacts to reduce information asymmetry and support offline participation in hybrid communities.

7.0   Discussion

My dissertation work consists of three studies to investigate the role of cross-boundary artifacts in reducing information asymmetry and facilitate offline participation in hybrid communities. Beyond the specific results of each of the three studies discussed in the previous chapters, I believe that taken together, the results provide key lessons to inform the design and study of hybrid socio-technical systems. These lessons together with guidelines for designing successful hybrid communities are summarized as follows.

Online v.s. Offline interactions in hybrid communities. Hybrid communities defined as "physical spaces intertwined with digital communities" emphasize the blended nature of online-offline interactions. To succeed, advance and sustain, hybrid communities not only rely on members' online participation but also on their engagements in offline interactions and transition between online and offline participation [21]. Our analysis of the interview study with event organizers of Meetup groups emphasized the importance of offline interactions. People are motivated by the opportunities to interact and contribute within the local space and also evaluate the success of their events based on the offline experience of attendees. Further, the quality of offline interactions were considered much more important than the number of people attending offline activities. Event organizers assess the quality of offline interactions by observing how engaging, interactive, and enjoyable the offline activities were. However, such information was rarely transferred back to the online space and thus often remains invisible for members who did not attend those events. Our results suggested that communicating those information of offline interactions in the online space allow members who did not attend those events to assess the success of such events and therefore supporting them to make decisions of attending future events in the same group.

On the other hand, online interactions are not considered as determinant metrics to assess the success of events nor of the community over time. People who build hybrid communities have the explicit goal of facilitating offline interactions among members. Thus, they do not consider the degree of online interactions as indicators of success in the context of hybrid

communities. However, we cannot overlook the role of the online platform. Although organizers do not anticipate high amount nor degree of interactions happening among members online, online platform makes their community more visible to a large number of people within the same geographic area and provides the opportunities to find more like-minded people to connect. Having a large amount of members joining the group online does not necessarily make organizers feel that their group is successful. However, they do see the opportunities of reaching more potential participants by the online presence of their group. For example, one of our interviewees said *"I'm happy that there are a lot people in the group, even though only maybe 10% of them have actually attended any events. I feel like there's the potential someday that they're going to see an event on the calendar that captures their interest and has availability on that date to come out.".* These results highlighted the importance of using the online platform as the venue and encouraging people who attended past events to share their experience of offline interactions. Our findings are in alignment with the opinions of researchers studies the hybrid communication models in early years. Sustaining both thriving online and offline interactions is essential for the health of hybrid communities [36, 70]. While online interactions may not directly impact the success of events and the community, the signals about offline interactions shared and communicated through online interactions among members can be useful to stimulate offline participation and therefore contributing to the success of events and communities over time.

Advantages of visual artifacts over textual artifacts. Comments and pictures are the two most common types of cross-boundary artifacts used in exemplary hybrid communities like Meetup groups. The results of this dissertation suggested both comments and pictures can be utilized as effective artifacts to communicate useful signals about offline happenings. However, our results also indicate differences between these two type of artifacts. From the perspective of viewers, visual artifacts are more intuitive and easily digested. A participant in our controlled experiments explicitly expressed his preference towards event pictures over comments because viewing pictures takes less time and cognitive effort: *"These comments are too long. I normally wouldn't read them. I prefer pictures much more. It's just easy and I'm a more visual person."* We know that pictures can convey rich information about offline interactions. Our results of online survey studies (in Chapter 5) showed that

people can easily infer a variety of signals from event pictures, including whereabouts, social dynamics, and success of events. In contrast, to encode the same amount of information, it will be difficult to keep the comments short and concise.

Furthermore, pictures are perceived as more reliable in terms of objectively communicate the quality of events to the online space. Specifically, comments are often used to convey personal opinions and feelings of an event where pictures can be more easily used to reflect objective happenings during the event. People consider the signals conveyed by pictures to be more trustful than comments because the cost of creating fake signals in pictures are much higher than in comments. Hence, to seek trustful signals, people usually need to review a larger amount of comments to assess the quality of offline happenings.

However, it does not necessarily mean pictures cannot communicate biased information. In our dataset of events organized by Meetup groups in two years, more than half of the event pictures (54%) were posted by event organizers while only 21% of the comments were shared by event organizers. The average number of distinct members who posted comments per event is 2.6 (Median = 2, SD= 2.8) while the average number of distinct members who posted pictures per event is 1.2 (Median = 1, SD = 0.6). Pictures can actually be used to deliver more polarized idea if there was often only one member share pictures of an event.

In short, the results of this dissertation recommend people use more visual artifacts to transfer offline happenings back to the online space in hybrid communities.

Low use of pictures in Meetup groups While the results of our studies in Chapter 5 and 6 suggested that visual artifacts such as pictures are good carriers to convey offline happenings in the online space, our results of the interviews in Chapter 4 showed that organizers do not use pictures much in Meetup groups. We observed two major barriers that prevent pictures from being widely adopted by organizers. First of all, people are concerned about the potential distraction caused by taking pictures during events as organizers often feel the need to lead offline interactions. Moreover, interviewees reported that the responsibility of taking pictures during event sometimes prevent them from enjoying the event in the moment. Secondly, organizers showed lack of confidence about the effectiveness of photos on conveying in-person interactions and facilitating offline participation. In particular, they concerned about the visibility of photos given Meetup.com today still does not present

photos of their past events on the webpage of upcoming events in the group. They don't believe that people will make effort to proactively browse photo albums of past events while looking for upcoming events to attend. The results of my studies in Chapter 5 and 6 indeed present the first piece of solid evidence that pictures can be utilized as effective artifacts to represent offline happenings and hence attract future offline participation. I expect the results of this dissertation to be used as guidance to advocate the use and presentation of pictures in Meetup.com to help build more successful hybrid groups.

7.1   Design Implications

Encourage more people to share cross-boundary artifacts. According to our two-year data of Meetup groups, cross-boundary artifacts are often generated by a few proportion of users in the community. In particular, the average number of distinct members who posted pictures per event is 1.2 (Median =1, SD = 0.6) while the average number of distinct members who posted comments per event is 2.6 (Median = 2, SD= 2.8). Encouraging more members to share cross-boundary artifacts can benefit the community in a number of ways. First, it helps to reduce polarized opinions shared in the online space and provide an more unbiased view of what happened offline. As we discussed previously, either textual or visual artifacts can present polarized opinions if only one or two members share them for an event. Having more people share those artifacts provide a better chance to present different perspectives about offline happenings in the online space; thus, it will be more likely to reflect the truth. Moreover, encouraging more people to share the responsibility of taking and sharing pictures can also help to ease the burden of event organizers. Our interviews with organizers showed that they sometimes feel overwhelmed by the responsibility of leading offline interactions while taking pictures at the same time. In addition, the shared-responsibility model can also help event attendees be more committed to the community [35]. Similar as in traditional online communities, allow members to take more responsibility and more leadership will make them feel more needed and engaged so they are more likely to retain and contribute more in the community.

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Intentionally present a mix of different signals. The results of our controlled experiments (in Chapter 6) suggested that people seek different signals from cross-boundary artifacts based on their primary goals as well as uncertainty level about the upcoming events. While offline interactions among attendees is the key metric for success, potential attendees may seek a variety of signals to help them make personal decision of whether or not participating offline. People may look for information about how interactive the technical workshops were if they want work in teams rather than individually. People may look for what kinds of food they often provided if they need vegetarian options. People may look for how advanced the previous biking events looked like if they prefer beginner-level activities. People may assess whether the view of nature is attractive if their goal is to experience the beauty of nature. We found the kinds of signals that are searched by a single person may vary based on their goals of participating in the community or their temporal needs or interests. Hence, we should consider to diversify signals presented in cross-boundary artifacts to provide information to potential attendees with different goals.

Personalized and customized representation of cross-boundary artifacts. The fact that people may seek different signals based on their temporal needs or interests suggests the implication of designing personalized or customized tools for members in hybrid communities to more easily search for signals they need from cross-boundary artifacts whenever considering to attend an upcoming event. As an example, technology designer may consider to introduce an automatic or manual tagging system which assigns labels to cross-boundary artifacts and therefore each artifact in the community will be labelled based on the kinds of signals about offline happenings it conveys. Similar to the tools provided by Yelp.com (see Figure 7), members can filter or search the pictures or comments of past events in the groups based on the type of signals that they need to help make the decision of attending a future event. Further, organizers can also add tags to the upcoming events they posted according to the kinds of atmosphere or offline interactions they expect. Thus, the system can automatically connect upcoming events with cross-boundary artifacts of past events based on the similarity of events. For example, a planned hiking events with entry level trail followed by a happy hour can be connected to pictures and comments of similar past events in which the trails were also easy and the drinks and environment of bars were presented. This

mechanism can effectively eliminate the problem of mismatch between event description and signals conveyed by cross-boundary artifacts of past events, described in section 6.4.
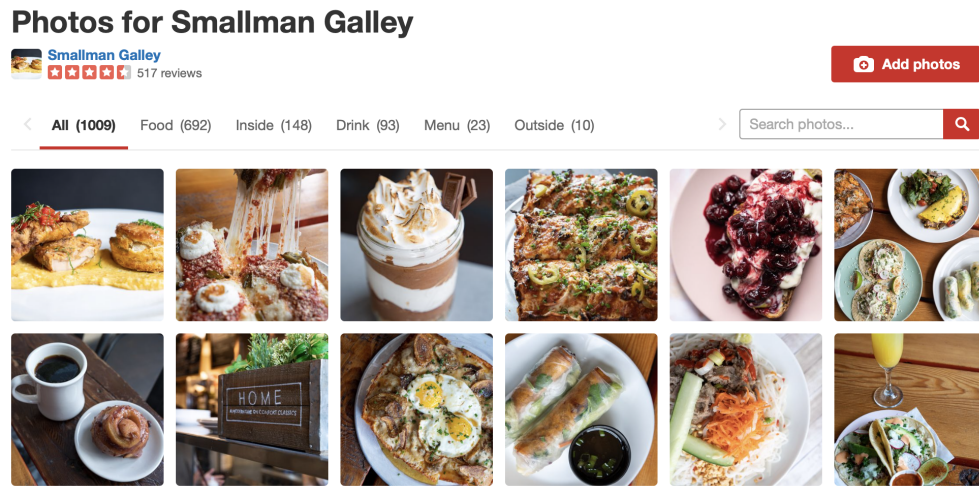

Figure 7: Picture filtering and searching tool provided by Yelp.com based on automatic tagging system

8.0   Contributions and Future Work

This dissertation focuses on the key challenge of *information asymmetry* in designing successful hybrid communities. I conducted a mixed-method empirical investigation on an exemplary hybrid community (Meetup.com) to provide a comprehensive understanding of the role and impact of cross-boundary artifacts in hybrid communities. The results of this work reveal that offline interaction is the core of hybrid communities as people are motivated by the opportunities to interact and contribute within the local space and also evaluate the success based on the quality of their offline experience. Further, our findings showed the necessity of sharing offline interactions back to the online space to reduce information asymmetry in hybrid communities. Moreover, our results indicate that cross-boundary artifacts can be utilized to convey a variety of useful signals to help members who did not attend the event to assess the quality of such event and therefore support people's decision making process of attending future events in the same group. This dissertation highlights the opportunities to design and utilize cross-boundary artifacts to support information transition from offline activities to the online space.

8.1   Contribution

The overall contributions of this dissertation for the field of Information Science as well as for our society in the era of information are summarized as below.

My dissertation work will contribute to the field of information sciences by:

1. Providing a fundamental understanding of socio-technical systems with hybrid interaction patterns, focusing on the success metrics and needs of connecting online and offline spaces;

2. Introducing a novel approach in considering cross-boundary artifacts as the key ingredient to reduce information asymmetry and support decision making in hybrid communities ;

3. Presenting an empirical examination on the role of cross-boundary artifacts on exemplary hybrid communities by conducting both quantitative and qualitative research and revealing the effect of cross-boundary artifacts on conveying reliable signals of offline activities and facilitating offline participation.

My dissertation work also contributes to better inform the design of socio-technical systems for hybrid communities as follows:

1. Assembling a number of lessons learned grounded on the results of the empirical investigation of a sample of hybrid communities on Meetup.com.

2. Compiling a set of evidence-based design guidelines tackling the challenge of bridging online and offline spaces in hybrid socio-technical systems as well as inform the design and practice of a broad set of hybrid communities that rely on online-offline interactions.

In my dissertation, I use Meetup groups as exemplary hybrid communities to investigate the role of cross-boundary artifacts by analyzing the use of cross-boundary artifacts in the group. I argue that the findings of this work can be generalized to other contexts. Below, I summarize a few examples to illustrate the generalization of my work.

- The design guidelines informed by the findings of my dissertation can be applied to other socio-technical systems designated for communities that aim to engage and mobilize members by participating in offline gatherings, such as Social Street Facebook groups [61] or E-democracy neighborhood forums [50].

- The methodology used to study the role of cross-boundary photos in Meetup groups can be also utilized with modifications to study other forms of cross-boundary artifacts such as short videos, live streaming videos, etc.

- The idea of considering shared artifacts as the key to build successful socio-technical systems can further be implemented in not only hybrid communities but any sort of communities as long as the following two requirements are met: (1) The community has logistical resource to support members to create and share artifacts in the community (i.e. physical devices to create artifacts, an online or offline mechanism to share artifacts among members, etc.) and (2) such artifacts are good carriers to represent the traces

of activities and dynamics in the community. Take an online group which aims to provide emotional support among people with mental disease as an example. Encouraging members to share stories of how they received support from the group in forms of short videos or written articles may be good carriers to represent the supportive interactions in the community; on the other hand, brief thank-you comments without details of their experience in the group may be less useful because such artifacts do not really show traces of the activities among group members.

This dissertation work have implications for information scientists, technology developers and community practitioners seeking to build successful hybrid communities in the era of information to connect, mobilize and engage people in the local space. Results from my dissertation inform the design of a broad set of hybrid communities that rely on online-offline interactions such as local event groups, neighborhood communities and local collaboration communities. Such hybrid communities can serve as platforms to strengthen our local communities through stronger engagement of residents in urban society.

8.2 Future work

This dissertation work focuses on the impact of cross-boundary artifacts on transferring offline footprints back in the online space and therefore bridging online and offline spaces in hybrid communities. However, I acknowledge that cross-boundary artifacts may serve other functionalities in hybrid communities. Below, I discuss several opportunities and potential directions of future research.

8.2.1 Archiving collective memories of hybrid communities

As mentioned in Chapter 4, some organizers considered sharing event photos as a mean to build group profile. They believed photos not only help present a better image of the group to attract new attendees but also create the memories for people who attended past event. Over time, event photos in the online space commemorate past events happened in

the group and achieve the collective memories for them. Socio-technical systems can easily utilize those photos together with other type of participation records such as RSVPs to create digital memories for members with events they attended and remind them with those past moments. Such technology has been used in implications like Facebook Memories to help people remember and celebrate their relationships and memories with friends. Similarly, this type of technology can be adopted to memorize and celebrate interactions among members in hybrid communities. It will be interesting for future research to investigate the effect such collective memories on people's commitment in hybrid communities.

8.2.2 Virtual participation via real-time cross-boundary artifacts

While my dissertation focuses on using artifacts to transfer offline footprints back in the online space after events, new technologies such as live streaming may support the connection of online and offline spaces in hybrid communities in a real-time manner. Sharing what happens in the offline space simultaneously in the online space may allow more members to interact with others in the offline activities even if they cannot physically present. However, this opportunities can also cause more burden for event attendees and may reduce their engagement in offline interactions. Hence, future research is needed to further understand the potential positive and negative effect of utilizing real-time cross-boundary artifacts.

8.2.3 Building social capital

The results of our interviews (See Chapter 4) showed that one of the major motivation of people participating and organizing events in hybrid communities is to look for peers with common interests and establishing inter-personal connections with others in the local communities. Some of them reported that their goals were well-fulfilled by participating and organizing events in hybrid communities. This results indicate the potential function of hybrid communities to the development of social capital [15]. A rich body of research has studied the function of online communities on developing social capital, but this concept is still new for hybrid communities. While this dissertation showed that utilizing cross-boundary artifacts can help bridge online and offline spaces in hybrid communities and

therefore facilitate future offline interactions, it is still unclear if such artifacts contribute to foster the development of social capital among members. In order to answer this question, researchers need to conduct future studies to probe how people develop and exchange social capital in hybrid communities and what is the role of cross-boundary artifacts in this process.

8.2.4　Polarization Effect

While we've discussed many positive impact of cross-boundary artifacts in hybrid communities, I acknowledge that there might be also negative consequence due to the use of such artifacts. One of the potential negative impacts could be the polarization effect. With more information of offline happenings shared by cross-boundary artifacts, it is also more likely to lead to polarization in participation. For example, if the majority of people presented in the past event photos is male, it is likely that less female will participate in future events in this group. Hence, it is important to keep in mind that polarized signals shown in cross-boundary artifacts may aggravate polarization in the community. To eliminate this impact, we encourage to diversify the signals in those artifacts. On the other hand, polarized signals transferred by cross-boundary artifacts may also lead to a cohesive group where members have similar goals and identities. Is that really a bad consequence or not to the local community or to the society? More future research is needed to better understand this question.

Appendix A

Interview Script

INTERVIEW SCRIPT

Introduction

 "Thank you for agreeing to speak with me today."

"The purpose of this interview is to get your insight about your participation, particularly organizing events in Meetup. Your experience can be informative for us to understand how systems such as Meetup can be designed more effectively and successful. We hope our research can contribute to improve your experience with Meetup and systems like Meetup."

"The interview will last about 45 minutes and I would like to audio record our conversation if that is ok by you. During the interview, I may also ask you to open and browse your Meetup account and ask you if you do not mind sharing your screen with me or talk about some of information regarding events you have hosted. You are free to skip any questions that you would like not to answer."

"Do you have any questions for us before we begin?"

"If not, can I get your permission to start recording our conversation now?"

Open questions

[Experience with group]
"Could you please describe in what ways you've been involved in [GROUP]? Do you often host or attend events?"

"How long have you been a member in [GROUP] and when did you start organizing events in [GROUP]? Do you remember it? What is that about? How did it go?"

"Do you remember what made you start organizing events in [GROUP]?"

[Recent hosting experience]

"Now, let's talk about the most recent events you have organized. Do you mind to show me that event page?"

"How did that event go? Did you have fun? What went well and what did not?"

"Would you consider that is a successful event? And why? Anything you would have done differently?"

"What would be your goal for organizing such events? Meet people? Meet new people? Meet old friends? Allowing people to interact with each other offline? Strengthen the connection among people? Did you achieve your goals?"

"Do you keep track of who attends your events? And do you compare that with online RSVP list? Do you do anything to encourage more responsible RSVPs?"

"Do you take a note of how many people who attend your events or RSVP for your events? Do you notice that before or during the event? Have you noticed what proportion of people attending your events are regulars and what proportions are new members or occasional participants? Is such proportion important for you to consider an event successful or not?"

"Have you noticed the interactions among event attendees during the event time? Is that important? Is that something that you'd like to achieve thru the event?"

"Which of the following aspects are important for you to assess the event you organized?"
- Offline space
    o Number of attendees
    o Number of new faces show up in the event
    o Number of old-timers attend in the event
    o Degree of interactions among event attendees
- Online space
    o Number of people comment, send messages about that event
    o Degree of interactions among members online
- Organizing
    o Organization and preparation of the event (online publish and offline logistics)
    o The collaboration with other organizers

[Practices of making the event successful]

"Over time, have you done things differently in how you organize events? Why did you do that and are your happier with that?"

"What did you do in order to make the events you organized successful? Do you have any specific routine or strategy for organizing successful events? If yes, how effective do you think they have been?"

[Artifacts and awareness]
"Do you do any follow-ups after your events? Posting pictures? Sending messages?"

"How well do you think members who did not attend the event know about what happened during the event?"

"Do you think it's important for sharing what happened in the events back to the group online? And why?"

[Success measures for the group overall]
"At what level do you think [GROUP] is successful? Why? OR What can be improved?"

"What do you like the most and the least about [GROUP]?"

"What are important for you to consider a Meetup group to be successful?"

(For those are not mentioned by the participants)
Now, I have a list of things and I'd like to ask you to tell me which of them are extremely important aspects and which of them are not that important when you consider whether a Meetup group is successful or not."

"How about these measures?"

- Continuousness
    o Number of events organized per month
- Online space
    o Number of members in the group
    o Number of new members join the group every month
    o Number of people comment, send messages about events
    o Degree of interaction among members online
- Offline space
    o Number of attendees per event
    o Proportion of members who ever attend the offline events
    o Number of new faces show up in each event
    o Number of old-timers attend in each event
    o Degree of interactions among event attendees
- Organizing
    o Organization and preparation of events (online publish and offline logistics)
    o Contributions of leader team

[System design]
"Do you think Meetup as a site, provide enough support for you as an organizer to host successful events and build successful groups? Are there particular supports you would like to be provided by the site with regards to that? "

"Any other thoughts or comments you'd like to share regarding newcomers?"

Appendix B

Questionnaire of Online Surveys

Questionnaire for online surveys

Your are shown a collection of photos that were taken during a local event hosted by a group in Pennsylvania.

Please carefully view the photos and answer the following questions based on what you learned from the photos.

[REMOVE PHOTO COLLECTIONS]

How many photos are included in the collection above?

_____

Approximately, how many people do you think had attended this event?

○ Less than 5 people

○ About 5 to 10 people

○ About 11 to 20 people

○ About 21 to 30 people

○ More than 30 people

○ I cannot infer that information from the photos.

What do you think the event is about?

○ A socializing event bringing a group of people together (e.g. a book club party, a dinner party, a birthday party, etc.)

○ An activity event where people meet get together to accomplish their goals of the activity, such as hiking, art making events, gardening, crafting, etc.

○ An technology-focused event such as hacking events, lectures, workshops, etc.

○ I think this event is about another topic:

_____

○ I cannot infer that information from the photos

- -

To what extent do you agree or disagree that people were really engaged during this event?

○ Strongly agree

○ Agree

○ Somewhat agree

○ Neither agree nor disagree

○ Somewhat disagree

○ Disagree

○ Strongly disagree

○ I don't know because I cannot infer that from the photo(s)

- -

To what extent do you agree or disagree that people were really interacting with each other during this event (such as talking, sharing, working together, etc.)?

- ○ Strongly agree

- ○ Agree

- ○ Somewhat agree

- ○ Neither agree nor disagree

- ○ Somewhat disagree

- ○ Disagree

- ○ Strongly disagree

- ○ I don't know because I cannot infer that from the photo(s)

To what extent do you agree or disagree that the atmosphere in this group was really enjoyable during this event (e.g. people were really having fun, the event seems to be interesting, etc.)?

- ○ Strongly agree

- ○ Agree

- ○ Somewhat agree

- ○ Neither agree nor disagree

- ○ Somewhat disagree

- ○ Disagree

- ○ Strongly disagree

- ○ I don't know because I cannot inform that from the photo(s)

Please provide 3 keywords that you think can best describe the events based on your observation of the photos.

○ Keyword 1 _____

○ Keyword 2 _____

○ Keyword 3 _____

- -

What else do you notice in the photos? Please indicate anything in the photos that draws your attention:

_____

_____

_____

_____

_____

End of Task

Appendix C

An Exemplary Task in Controlled Lab Experiment

Event Page with basic event information

Event title:

September happy hour

Description:

Please come join us for a happy hour party at Full Moon Brewing Co..

If you have never been to The Full Moon Brewing Co. you will hopefully enjoy the ambiance of this place. They also offer a diverse beer list, some great food options and a fun environment. Looking forward to seeing those who sign up.

Hosted by: Bryant

From: Pittsburgh social group

After carefully reading the event information above, please answer the following questions.

On a scale from 0 - 10, how likely are you to attend this event? *(Please remember to assume that both the time and location work for you)*

Not at all likely										Extremely likely
0	1	2	3	4	5	6	7	8	9	10

On a scale from 0 to 10, how confident are you in your decision to be satisfied with this event when you attend it?

"10" means that with the information you have about this event, you are completely sure that you would like or dislike the event if you attend it; while "0" means that you feel uncertain about whether or not you would like the event based on the information you have about this event.

Not at all confident   Extremely confident

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

Event Page with Cross-boundary Artifacts (Condition 1)

Event title:

September happy hour

Description:

Please come join us for a happy hour party at Full Moon Brewing Co..

If you have never been to The Full Moon Brewing Co. you will hopefully enjoy the ambiance of this place. They also offer a diverse beer list, some great food options and a fun environment. Looking forward to seeing those who sign up.

Hosted by: Bryant

From: Pittsburgh social group

Photos from prior similar events in this group:

Your previous answers:

- How likely are you to attend this event? **8**
- How confident are you in your decision to be satisfied with this event? **8**

With the additional information about prior similar events in this group, please answer the following questions.

On a scale from 0 - 10, how likely are you to attend this event? *(Please remember to assume that both the time and location work for you)*

Not at all likely										Extremely likely
0	1	2	3	4	5	6	7	8	9	10

On a scale from 0 to 10, how confident are you in your decision to be satisfied with this event when you attend it?

"10" means that with the information you have about this event, you are completely sure that you would like or dislike the event if you attend it; while "0" means that you feel uncertain about whether or not you would like the event based on the information you have about this event.

Not at all confident										Extremely confident
0	1	2	3	4	5	6	7	8	9	10

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