Design for Collaborative Information-Seeking: Understanding User Challenges and Deploying Collaborative Dynamic Queries

SUNGSOO (RAY) HONG, New York University, USA
MINHYANG (MIA) SUH, University of Washington, USA
TAE SOO KIM, KAIST, Republic of Korea
IRINA SMOKE, University of Washington, USA
SANGWHA SIEN, University of British Columbia, Canada
JANET NG, University of Washington, USA
MARK ZACHRY, University of Washington, USA
JUHO KIM, KAIST, Republic of Korea

Although Collaborative Information-Seeking (CIS) is becoming prevalent as people engage in shared decision-making, interface components adopted in the most commonly used information seeking tools (e.g., search, filter, select, and sort) are designed for individual use. To deepen our understanding of (1) how such *single-user designs* affect people's consensus building processes in CIS and (2) how to devise an alternative design to improve current practices, we conducted two 4-week diary studies and observed how groups seek out places together. Our studies focus on social event coordination as a case where CIS is necessary and important. In Study 1, we examined the major challenges people encounter when performing CIS using their preferred tools. These challenges include difficulties in capturing mutual preferences, high communication cost, and disparity of work depending on a group member's perceived role as an organizer or invitee. We discovered that improving a group's shared understanding of the target information they seek (e.g., places, products) could potentially address the challenges. In Study 2, we designed, deployed, and evaluated *ComeTogether*, a novel system that supports a group's social event coordination. ComeTogether adopts Collaborative Dynamic Queries (C-DQ), an interface designed to allow a group to share their preferences regarding potential destinations. Study 2 results indicate that using C-DQ increased users' awareness of other group members' preferences in performing CIS, making their coordination more transparent, more inviting, and fairer than what their current practice allows. Meanwhile, ComeTogether improved communication efficiency of groups while presenting opportunities to learn about others and to discover new places. We provide implications for design that explain considerations for adopting C-DQ and identify future research directions.

CCS Concepts: • **Human-centered computing → Empirical studies in HCI**; **Collaborative and social computing systems and tools**.

Authors' addresses: Sungsoo (Ray) Hong, rayhong@nyu.edu, New York University, New York City, NY, USA; Minhyang (Mia) Suh, miasuh@uw.edu, University of Washington, Seattle, WA, USA; Tae Soo Kim, kimts96@kaist.ac.kr, KAIST, Daejeon, Republic of Korea; Irina Smoke, idsmoke@uw.edu, University of Washington, Seattle, WA, USA; Sangwha Sien, swsien@cs.ubc.ca, University of British Columbia, Vancouver, British Columbia, Canada; Janet Ng, janet.m.ng@gmail.com, University of Washington, Seattle, WA, USA; Mark Zachry, zachry@uw.edu, University of Washington, Seattle, WA, USA; Juho Kim, juhokim@kaist.ac.kr, KAIST, Daejeon, Republic of Korea.

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1 INTRODUCTION

People seek information together with their friends, family, and colleagues to make decisions about where to go [16], what activities to do together [34], or what to purchase [68]. Traditionally, information seeking has been considered a solo activity [5], but advances in technology have enabled Collaborative Information Seeking (CIS) to become commonplace [58]. Researchers in the CSCW and HCI communities have actively studied CIS as a major research area, and explored how to make CIS more 'collaborative' to better support group decisions through understanding the CIS practices [59]. Findings indicate that people engage in CIS more frequently now than they did just a few years ago [50], and the information that groups share in CIS is becoming more diverse, ranging from simple properties (e.g., price range of a product) to more complex and collective forms of knowledge (e.g., learning about specific topics in detail online) [38].

Despite the growing prevalence of CIS and the diversifying information exchanged in information-seeking processes [38], researchers note that user interfaces in everyday information-seeking tools are designed for single-user scenarios [50]. For example, while people use various interface components for searching, filtering, selecting, and sorting target information [24], the knowledge that individuals develop while engaged in the seeking process (e.g., preferred brands, price ranges) cannot be effectively shared with others [14, 31, 50]. Hereafter, we use the term *single-user design* to refer to user interface designs that are not created explicitly to support group information seeking. In this work, we pay special attention to the challenges single-user designs pose for CIS and explore how to design beyond the single-user paradigm for CIS. Studies show single-user designs isolate individuals' seeking efforts and the knowledge that these individuals develop during the seeking process [31, 38]. However, little research has focused on understanding how current tools built based on single-user designs guide people in their CIS processes, what struggles people encounter, and how new group-oriented technologies could be designed to address these challenges.

To understand how to better support CIS beyond single-user design, we conducted two studies. The first study (S1) was designed to develop a deeper understanding of how people currently use widely adopted single-user design interfaces to collaboratively seek information and discover what challenges they encounter. We thus conducted a diary study with 20 people over 4 weeks to develop a detailed picture of how participants collaboratively seek places for coordinating their social events, and the challenges they face when making group decisions. We chose social event coordination because it is a common scenario that people encounter [57] and CIS plays a critical role in that process [4]. Based on our observations, we uncovered a design opportunity to ease the struggles we observed. We thus devised *ComeTogether*, a system that helps a group seek places as they coordinate a social event. Fig 1 shows a main screen in ComeTogether. In the second study (S2), we sought to understand whether and how using ComeTogether might improve CIS in social events coordination. Below, we will provide a brief overview of our findings from S1 and S2. We will then explore related work in this area, present detailed descriptions of S1 and S2, discuss our findings across the two studies, and offer the implications for design emerging from this work.

In S1, we discovered that participants had minor struggles with sharing the outcomes of individual seeking processes using available features in the tools they used (e.g., a "share" button to suggest a

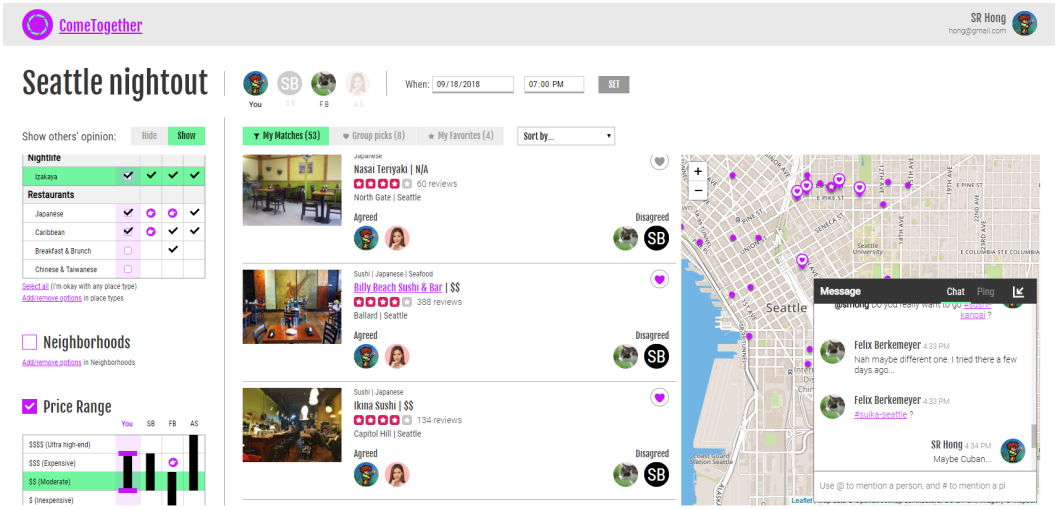

Fig. 1. A screen of ComeTogether: Redesigned C-DQ (left), a list view (middle), a mapview (right) are presented. A user can chat with group members using a chat window (bottom right).

place to a group). However, participants expressed that it was often difficult to explain the *rationale* behind the outcome of their preferred choices to other group members. Such difficulties contributed to increased communication cost for reaching consensus, resulting in delayed outcomes for their CIS and/or sometimes failing to coordinate their event after all. Interfaces designed for individual use do not support group members wishing to easily share their thoughts and preferences *while* they are seeking information, and they lead users to build individualized perspectives. Such individually developed perspectives vary from one group member to another, resulting in increased cost of communication for reaching group consensus. As Schuler notes, high cost in reaching consensus may contribute to making people's CIS for social event coordination more of an act of 'satisficing' rather than enabling them to make optimal choices for the group [57].

Based on the findings of S1, we designed and deployed *ComeTogether*, a novel system that helps a group to share perspectives about the places for coordinating social events. To tackle the user challenges we identified in S1, ComeTogether adopted *Collaborative Dynamic Query* (C-DQ), a design that enables group members to both share their own individual preferences and see the group's mutual preferences regarding decision criteria [31]. In S2, we conducted another diary study and observed how groups use ComeTogether to coordinate social events. We found that exposing C-DQ in ComeTogether increased group member's mutual awareness of each other's values and preferences during the process and enabled them to more actively participate in CIS. Participants felt that using C-DQ led to more evenly-distributed information seeking efforts, which increased their perceptions of fairness about the work involved. Participants felt that, compared to their current practices, using ComeTogether made their communication more efficient and their coordination more mindful of others. Finally, ComeTogether led participants to discover new places that they had never experienced before.

This work offers the following contributions:

- **Findings in S1**: We present findings that deepen our understanding of how people engage in CIS using tools based on *single-user design* in social event coordination. We describe how existing tool designs presented challenges for participants' information seeking and decision-making, providing insights into redesigning for CIS.

- **System and Technique**: We present *ComeTogether*, a novel system that supports a group's social coordination events, along with a new design of C-DQ, which designers could adopt for building groupware to support CIS in various scenarios.
- **Findings in S2**: Along with ComeTogether, we present findings that explain how using ComeTogether changed people's behavior and perception in performing CIS and improved their social event coordination.
- **Implications for Design**: Drawing upon our findings in S1 and S2, we provide *design implications* that explain considerations for adopting C-DQ and future research directions.

2 RELATED WORK

Even with the support of current technologies, activities involved in CIS, such as seeking information in a group, understanding and addressing conflicting opinions among members, and reaching a consensus, can overwhelm people [58]. We review people's experiences while they engage in group collaboration and CIS, and show how research in CSCW, CHI, and Information Visualization (InfoVis) communities have improved people's group experience. We then discuss the gap between existing technological approaches and the current practices people employ in CIS.

2.1 Work Disparities in Collaborative Information-Seeking

When groups attempt to accomplish tasks together using information systems, they frequently experience a disparity of effort among team members [18]. Such disparities can increase the overall effort required to coordinate different opinions among group members [47]. In an influential study of the design of workplace groupware, Grudin addressed the need for systems to more equitably distribute effort among group members to minimize disparity between those who benefit from the work and those who perform it [18, 19]. Beyond groupware systems, disparity also exists as a problem in CIS more generally [57], causing a variety of negative effects. For instance, studies have demonstrated that perceived unequal contribution in CIS can lead to social loafing [40], free-riding [37], and production blocking [39]. Effort disparity can also cause inconsistencies in shared knowledge, making it hard to track issues and derailing conversations [57]. Effort disparities sometimes also lead to non-transparent decisions made only by one or a few group members [47]. For instance, Schuler et al. observed that one or a few members often take on the role of actively seeking information while the rest merely "relay" information without genuinely seeking it while the group is coordinating social events, [57].

With the increasing prevalence of CIS in people's everyday practices, researchers have investigated techniques and systems to make CIS more inclusive and distributed. Researchers have explored various applications, including collaborative web search, social coordination, location co-searching, and e-commerce. For instance, *SearchTogether* and *CoSearch* propose a collaborative web environment where groups can seek and review online information together [5, 51]. Picken et al. and Golovchinsky et al. presented an algorithmic mediation that helps a small group's collaborative and exploratory search [17, 52]. In supporting group's social coordination, Barkhuus et al. show that sharing location information with one's social group helps make their social coordination more enjoyable [8] and Teevan et al. introduced a mobile based collaborative place search application in which each user could switch modes between individual and collaborative search by rotating the device [62]. Findings in Yue et al.'s study of shared views for collaborative shopping [68], Bently et al.'s study of travel time sharing [10], *SearchMessenger* [11], and Wei et al.'s studies *food messaging* [66] all suggest an opportunity for creating new interaction techniques that externalize a group's activities and/or specific information about members relevant to the task context. Such interaction techniques, this research suggests, has the potential to improve people's ability to engage in CIS, and to support more intimate experiences in such work.

2.2 Mode of Communication in Collaborative Information-Seeking

The heavy use of text-based communication presents several challenges for CIS. Although text-based chat plays a dominant role in CIS [57], studies show that it often fails to fairly capture opinions within the group [31, 43]. For instance, text-based communication can be dominated by individuals with higher social status, with dominant personalities, or with strong opinions, making it hard for others to engage in a discussion [35]. Additionally, relying on text-based communication to express nuanced and contextualized intention or assess the dependencies and trade-offs between different opinions [43] is deemed taxing [41, 46] or not possible [1]. Aldosari et al. found that people feel coordinating place seeking is hard and often includes redundant effort [4].

To tackle this challenge, researchers have aimed to improve social communication with novel *interaction techniques*, enabling efficient group information exploration or evoking positive coordination experiences. For instance, *scented widgets* visually externalize other users' navigation behavior alongside a widget [67] as a form of supporting *social navigation*. Hong et al. presented Collaborative Dynamic Queries (C-DQ), an interaction design that allows a group to indicate and see mutual preferences in a small group decision-making scenarios [31]. Hajizadeh et al. present *collaborative brushing and linking*, an interaction that enhances awareness when a group explores multifaceted visualizations [20]. Another line of research is building *systems* that provide awareness of a group's activity [23]. For instance, *ManyEyes* [64] and *Sense.us* [25] presented a public online space where people can collaboratively create visualizations and discover insights. Additionally, systems such as *Cambria* [33], *We-Choose* [21], and *ConsensUs* [43] contribute to collaborative search in specialized contexts.

Despite this body of research aimed at improving current CIS practices, the design of user interfaces adopted in most information-seeking tools lacks features for explicitly supporting a group performing CIS [50]. Members of groups, consequently, must find information and knowledge about it using tools based on single-user designs and then turn their private judgments into a collective decision later with the use of an auxiliary communication tool. These studies have informed us about difficulties people encounter when collaboratively using information systems. To our best knowledge, however, no previous study has closely considered how decentralized seeking efforts using single-user designs affect people's CIS processes. Investigating the impact of the single-user design on CIS, we contend, can yield insights that can make CIS experiences more "democratic" and "inclusive", which are important for effective group collaboration [44].

3 STUDY 1. DIARY STUDY: USING SINGLE-USER DESIGN IN CIS

In S1, we conducted a 4 week diary study to understand participants' practices and challenges when they engaged in CIS using tools built based on single-user design. We aimed to answer the research question as follows:

- **RQ**. How do people organize a group and perform CIS together while using tools built based on single-user designs and what user challenges do they encounter?

We focused on observing how people coordinate their social events where CIS is necessary and important [57]. We present the themes that describe the challenges that participants experience in CIS and develop design rationales for a new system that could potentially address the challenges.

3.1 Methodology

To recruit participants, we used email lists at a public university in the US, Craigslist, and Facebook local groups. We recruited 20 participants (12 female, 8 male), each of whom reported they seek information for coordinating social events at least once per week using tools such as destination recommendation systems (e.g., Yelp, Airbnb) and map tools (e.g., Google Maps). Their age groups

were: 18-24 (28%), 25-34 (57%), 35-44 (10%), and 45-54 (4%) years-old. We asked participants to complete a daily survey for 4 weeks. On days when they engaged in coordinating events, they documented the event details (e.g., the activity type, the tools they used) as well as their coordination experience (e.g., roadblocks they encountered) in the survey. We thus collected data related to 146 social gatherings (7.3 events per person). At the end of the study, we conducted online interviews with every participant. Using the diary entries as a memory aid, we shared participants' entries back to them and asked about their coordination experience for each event.

All qualitative data was transcribed and analyzed using a grounded theory-based affinity analysis. Our methodology is largely based on affinity diagramming in Beyer and Holtzblatt's work [29] while we used actual quotes as a unit of analysis as opposed to relying on researchers' interpretations. These quotes served as the basis for further categories and themes, following the priorities of a grounded-theory approach [22]. During the analysis, a team of five researchers continuously discussed and iterated codes, categories, and themes together until mutual agreement was reached. Our methodological decision is based on previous works focusing on organizing and grouping large quantities of subjective data into a logical set of categories and themes (e.g., [6, 9, 13, 48]).

All interview records were transcribed. The five researchers separately read through subsets of transcriptions (four each). They then created initial codes altogether. Using these initial codes, each researcher coded another subset of four different transcriptions. All the quotes were parsed into notes comprised of 1 - 3 sentences that contain a single idea (code). Then, the five researchers gathered and grouped these notes together. They discussed labels for each group while resolving the conflicts around assigning codes, groups, and labels. Once all agreed on the groupings, they reviewed the diagrams together to ensure that everyone had a shared understanding of the meaning of the labels for the groups, and engaged in affinity-diagramming the groups of groups together to form categories. After this, two researchers reviewed each category to generate themes and iteratively discussed the data as a whole until both agreed with a single narrative that reflects the challenges of participants engaged in CIS using tools based on single-user design. The diary responses were also analyzed using statistical tools to describe the dataset. The themes and descriptive statistics are discussed with illustrative quotes and examples below.

3.2 Results

Overall, study participants coordinated a social gathering every other day (daily 0.5 events per person) and about 3.3 people participated in each gathering on average. Participants looked for varied places (n=152) including restaurants (48%), cafes/bars (12%), movie theaters (8%) or study places (3%). 86% of social gatherings that participants coordinated (n=126) involved a variety of tools including text messaging apps (e.g., Facebook, Google Hangout, WeChat, WhatsApp), email, map applications (e.g., Google Maps), and destination recommender systems (e.g., Yelp, TripAdvisor, OpenTable). In interviews based on the diary entries, we delved into how participants co-searched for information to make a group decision, and what kinds of challenges they faced in doing so. The major challenge that participants faced in their group decision-making for a social gathering was *"finding somewhere that fits the constraints that everyone [has], [so] that people feel like their voice is heard"* (P5). We found that various factors must potentially be communicated during CIS such as price, location (P12), availability (P8), skill-level (P13) and reviews (P8) when a group is making a decision, and participants indicated that it is not always easy to accommodate everyone's preferences. For example, P15 noted that, *"Some people don't eat this, some people don't eat that. And you know people don't want to drive, and some people don't drive so, you know, [it] becomes an issue . . . [in] a larger group, of course. it becomes more difficult to like keep everybody happy."* Participants noted that it is important to create common ground for a group decision that everyone is happy with. This, however, poses challenges, as described next.

3.2.1 Knowing Others' Preference is Hard. Participants sometimes found it difficult to know the preferences of others. Not everyone prefers to express their opinions (P3, P12), while others said it felt "rude" (P5) to be explicit about one's own preferences, especially when that preference is not shared by others. Not clearly knowing other's preferences often led to a prolonged group decision-making processes. P6 recalled his frustration when none of his friends were decisive about where to go: *"Nobody could make up their minds, so it was a little difficult to figure out what we were going to do . . . we essentially thought we were wasting our time hashing out the details when we could have just chosen a place and rolled with it."* This effect was exacerbated if the group did not know each other well. For example, when helping organize a friend's wedding, P12 found it difficult to book an AirBnb location for a couple that she knew only though a friend. She remembered how tedious it was to go back and forth, politely asking questions: *"What level of niceness are they looking for? So, like, financially, are they able to spend more, spend less, I had no idea . . . it is hard to just write them saying, 'Hey, what's your financial situation?' Or 'How picky are you about having nice things?' "* Participants went on to explicitly express their desire to know others' preferences, with P2 stating: *"When everybody makes their limitations or desires clear, that can make it really quick and harmonious because you can keep everything in mind without having [to go] over and over [it]."* P4 also wished she could see what her friends were looking for: *"[If] you could see where this person already looked [at a] place, and it's like, 'okay I kind of like that place too' just to get an idea of what people are looking for."'* At times, participants felt that existing tools were not as conducive to sharing preferences as an in-person conversation: *"I feel like you can tell what a person really wants when you're in person rather than over the phone or over text. Then, people [are also] more wiling to give their input of a place to go instead of, 'I don't care."'* (P11).

3.2.2 Group-Communication Cost is (still) High. Despite the use of communication technologies (e.g., text, Facebook Messenger, WeChat) participants reported feeling that it often took too much time to coordinate social gatherings. Some participants blamed this on 'the number of people' involved: *"it just takes a lot of time to get input from that many people"* (P13). When group sizes were larger, participants said it was hard to keep track of messages: *"It gets a little bit annoying when I hear like 40 messages within like 10 minutes. So I have to like go back to what's happening, to what everybody said, this and that. So I think that's my only problem with groups larger than like five."* (P15). We also found that there is no systematic support for participants to share the reasons behind their choices. For example, when P12 and her friends individually sought potential places to stay together, she had to explicitly explain why she chose certain options: *"I ended with four options that I sent to the group on WhatsApp, and I sent a little name for what the property was, and then I put the link, and then I wrote how much it cost per person per night for each of us among the four."* Diverse values caused *"back and forth communication"* (P5) to build a consensus: *"it takes time too, like the print screens sent there and then they answer, sometimes we take another print screen, 'Oh, here's another option.' And sent back. (P9)'*

Asynchronicity in current tools with single-user designs exacerbated the communication costs for relaying individual preferences. Back and forth communication often took longer than participants desired: *"I sent that out and waited for reactions from everyone else. That took a little bit of time. We went back and forth, back and forth... I was really just trying to go for location, some level of niceness and cost. And, those were my three variables, right? But, there's just so many more [values to communicate]"* (P12). P15 also mentioned, *"it was just annoying because it was just a bunch of messages that like keep beeping the whole time. So I had to like turn it off. Like shut Facebook down."'* While technologies allowed for synchronous communication, participants noted that cycle times still sometimes stalled the flow of group conversation. P5 remembered how her group chat

was intermittent, rather than continuous, while she kept waiting for other's responses: *"message someone, wait, message someone, wait."*

Participants noted that group communication felt more burdensome when using several technologies together due to "switching" costs between the tools, such as Google Maps, Yelp and text (P8). In fact, participants used, on average, 2.4 different tools (ranging from 1 to 10, SD=1.46) to coordinate a single social gathering. To reduce these costs, participants devised their own means of communication. P14 and his friends individually listed the potential places to visit in a chatroom, and voted to decide where to go; P16 ended up having a video-chat after a few hours of texting each member of the group. P13 and her friends shared a document via Google Doc to aggregate ideas about where to go or what to do together- an approach that does not require excessive back-and-forth communication, or waiting time for responses. However, she also noted a limitation to the approach as a group communication channel: *"We looked at different websites and found some and put . . . links to a few and wrote down the distance and the difficulty of each . . . we were each writing comment in the document in different colored fonts or whatever, but it wasn't always clear who wrote what. If one person wrote, like, 'This sounds good,' and the other person wrote, 'I don't want to do this,' it wasn't always clear who wrote which comment."*

3.2.3 Different Expectations among an 'organizer' and 'invitees'. Participants found it difficult to learn about and communicate individual group member's preferences. This was exacerbated by individuals' self-perceived role as either an organizer (who actively perform CIS) or invitee (who play passive roles in CIS). Many participants (76%) had a clear sense of whether they were coordinating a specific event as an organizer (45%) or attending it as an invitee (31%), and they reported different expectations about group decision-making, respectively. For example, P3 noted, *"If I'm the main organizer I need to make suggestions. As an invitee, I just need to either approve or reject or suggest something else, but I don't really have the pressure to find a place."* P16 also said, *"I find it easier for me to have somebody else be in charge because then I don't have to be responsible for anything [and] I don't feel obliged to look for different places, but when I am [the] main organizer, I have to look for different places and try to have everybody satisfied, which sometimes [is] really challenging."*. Similarly, P6 described different roles when looking for a specific restaurant: *"We all knew we wanted Shawarma...the lead guy was more or less putting out some of the shop names and then we just went with [this restaurant] after [we] did our own little searches on what was on the menu."* Participants thought that an organizer naturally *"just feels more invested in the outcome of what's going on"* (P7), which often leads them to become an *active seeker* who takes on the extra work of *"making sure that it meets everyone's needs, rather than being more along for the ride"* (P7). Participants observed being an organizer can be stressful; in particular, *"at times people are either too picky within my group, or they're open to anything at all so it doesn't really help us narrow things down"* (P9). At the same time, invitees do not necessarily feel compelled to be actively involved in group seeking information. For example, P15 did not feel the need to read all group messages or get involved until the rest of the group had narrowed down the choices: *"If I am not organizing, basically I just wait until people decide on what to do or reduce it down to like two options. I can go back and choose the one I want or give my feedback."* P8 noted the pros and cons of being a passive invitee, comparing that experience to her experiences as an organizer: *"I just have to be more laid back when I'm not planning it and willing to go with the flow because I'm not gonna take the time to plan it. Then I kind of have to be willing to do what other people want to do."* Being an invitee may mean being willing to compromise on personal preferences and follow others: *"With the same group of MBAs, we decided to go to an Indian place, and I'm not a huge fan of Indian food, so I say, 'Well, it's okay let's go there' "* (P9). Unfortunately, there was no systemic support available to mitigate these different expectations, and groups ultimately had to rely on organizers to make decisions.

Challenges	Design opportunities	Possible feature(s)
Knowing others' thoughts is not easy	Increasing group awareness [60] so that group members can track on others' preferences	Redesigned Collaborative Dynamic Queries [31] (e.g., preferences-on-criteria, preferences-on-candidate)
Communicating with others takes time and effort	Presenting communication modalities other than text-based communication for easy and unobtrusive suggestions	Shortcuts for asking other members in a group to agree on filter range or a specific candidate
Unbalanced seeking effort based on role	Lowering participation barriers of CIS and make decision-making more "explicit" to everyone [44]	Notification feature, explicit consensus-making process such as voting

Table 1. User challenges identified in S1 and possible solutions

3.3 DISCUSSION

In S1, we identified three major challenges that participants faced in CIS. We discuss how using single-user design in CIS can contribute to diverging each member's *schema*, an individual's knowledge or knowledge structure [16] that one gradually gains while seeking information [53, 56]. Next, we discuss how the diverging schemas can be related to the challenges we identified. Finally, we discuss design features that could facilitate a group's shared schema to improve current practice (See Table 1).

We speculate that the tools built based on single-user design present limited capability for sharing members' thoughts and preferences. Seeking–when it is mediated by single-user designs–does not allow a given group member to understand other people's mutual interests and preferences. For instance, participants used existing features, such as a "share" button, to suggest places to others in the group. However, participants often experienced difficulty in sharing the reasoning behind the outcomes of their individual efforts with others. Sharing only an outcome conceals one's effort behind the choice, which often includes seeking for multiple candidates and comparing them using a set of criteria. In other words, single-user design help members to share *what* rather than *why*.

Such insufficient support for presenting reasons behind an individual's choice using existing tools may lead each group member to seek information without referencing others. Such *decentralized* seeking may lead each member to develop their own constraints, preferences, and rationale for assessing candidates in their own way. Such decentralized seeking could lead to divergent schema among group members. In addition, the different engagement levels according to perceived roles as either organizers or invitees could exaggerate the decentralization of group schemas by widening knowledge gaps. However, studies show that environments that do not effectively facilitate shared schemas negatively affect a group's CIS in many ways. For instance, such environments can reduce the opportunity for group members to learn from each other [38], leading people to put redundant effort into seeking information [45], and hamper groups in establishing a shared grounding [63, 68]. Scheler similarly found that inconsistencies in shared knowledge make it hard for a group to track issues and derail conversations in the coordination of social events [57]. The three user challenges we identified in this study seem to be closely connected to these previous findings.

Most current tools used for seeking information while coordinating social events allow members to share found outcomes only *after* they finish seeking information. We saw the opportunity to design new groupware that moves beyond single-user designs, enabling group members to easily share their preferences with others *while* each of them are engaged in CIS while facilitating shared schemas. Table 1 presents user challenges, design opportunities, and possible features that could address these user challenges. We will explain how we used these insights to build a new system in Section 4.

4 STUDY 2. DEPLOYMENT STUDY: COMETOGETHER

In S2, we aimed to understand how exposing a new system design based on the insights we uncovered in S1 to groups might change people's behaviors and perceptions while engaged in CIS. In developing our system, we aimed to support people in the wild as they form a group, seek an activity type, location, and date, and make a decision together.

In S1, we discussed how presenting a group communication mechanism that would enable group members to easily indicate their preferences while being aware of others' may help make CIS more inclusive and synchronize schemas among those involved. A *Dynamic Query* (DQ) is a widely used interface component that individuals can leverage to build their schema while seeking information [12, 61]. DQ has been adopted as an integral feature in everyday information-seeking tools. *Collaborative Dynamic Queries* (C-DQ) is an interface component that extends the design of DQ to collaborative environments, enabling each member in a group to specify their preference ranges while also seeing other members' preferences at the same time [31].

C-DQ can be an effective design for synchronizing a group's schemas while engaged in CIS. To date, however, C-DQ has been only studied in lab experiments and has limitations:

- **Fixed collaboration scenarios**: C-DQ was designed only for synchronous and distributed collaboration scenarios. Social coordination in the wild, however, can be co-located or distributed, as well as synchronous or asynchronous [65].
- **Fixed group dynamics**: C-DQ was designed for four people who identify as close friends. However, collaboration patterns can greatly differ depending on number of group members [15] and the relationships within the group (e.g., family, friends, colleagues).
- **Fixed criteria types and ranges**: C-DQ was tested in fixed criteria type and range. However, the criteria used in real-world scenarios often include numerous options (e.g., 309 place options are listed in the "Restaurant" category in Yelp as of 12th of September in 2018) [7]) so groups must be able to selectively and flexibly add/remove the options "on-the-fly" while performing CIS based on their situation and needs.

4.1 System: ComeTogether

We uncovered two design requirements that need to be implemented to successfully resolve communication bottlenecks in CIS for social coordination: (1) redesigning conventional C-DQ so that it can work robustly in the wild and flexibly accommodate real-world users' dynamic needs and complex usage patterns, and (2) identifying and building a series of design features beyond the fundamental components of C-DQ that are required for supporting the life cycle of social coordination, including group formation, seeking information, building consensus, and making a decision.

4.1.1 Design Process. ComeTogether is the product of a collaborative effort by a team of 2 UX designers, 2 developers, and 4 user researchers. An initial system was built based on Hong et. al's work [31], which included C-DQ, list, map, and chat modules for supporting groups collaboratively seeking for social places. After the team built its initial system, we recruited 12 beta users and led them to use ComeTogether for coordinating their social events. Following a user-centered design (UCD) process for 6 weeks, we asked the beta users to report issues they discovered through email and a weekly survey. As we received feedback from the beta users, the researchers collected the issues and categorized them as either usability problems or requests for new features. Usability issues were reported to developers and fixed immediately. New features were implemented after designers revised UI flows. At the end of the UCD period, we conducted closing interviews with our beta users to collect overall experience reports about using ComeTogether, and to identify further issues to be addressed for supporting smooth social coordination. After the closing interviews,

researchers and designers analyzed the interview transcriptions to categorize the issues using affinity diagrams and selected new features to incorporate into a final version of ComeTogether to be deployed. Throughout the process, we handled 16 major UI flow revisions and 450 issues over a total development period that lasted 6 months.

4.1.2 Requirements of C-DQ and ComeTogether. We discovered several requirements throughout the design process. We explain two types of requirements; **design requirements** that show how the original C-DQ suggested by Hong et al. [31] could be improved, and **system requirements** that explain what features other than C-DQ that ComeTogether should present to smoothly support people's social event coordination tasks in the wild.

Fig. 2 shows redesigned C-DQ. The design Requirements for C-DQ are as follows (Note that a profile image along with initials was used for member identification in the interface (see Fig. 2 (a)):

- **Nominal C-DQs**: Our users mentioned that nominal C-DQs, such as Place Types and Neighborhoods (we included the Neighborhood C-DQ in our final system) were the most useful C-DQ features. In designing these nominal C-DQs, we found unique user demands. First, nominal C-DQs can include several options so presenting a clear visual hierarchy between categorical options helps users to efficiently scan through feasible options (e.g., "Restaurants" include "American" and "Chinese" in Fig. 2 (b)). Second, we found that users preferred to have the ability to change options after starting an event. Thus we enabled the capability for groups to change options when necessary (e.g., "Add/remove options" bottom in Fig. 2 (b)).
- **Group Size**: Many users mentioned that seeing everyone's specific preferences became less useful once many members were involved. Therefore, we gave users the option to view either (1) details about everyone's individual preferences (a *default view*, see Fig. 2 (b), left) or (2) a summary showing how many users have agreed (a *summary view*, see Fig. 2 (b), right). In our implementation, we presented this toggle option for groups of between 3 and 5 based on user feedback. We presented only the default view for groups of 2 and only the summary view for groups with over 6.

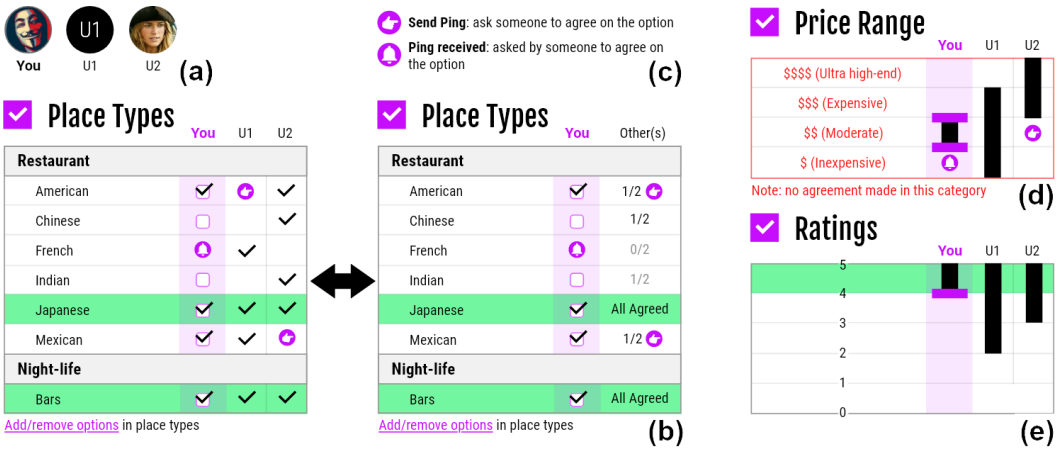

Fig. 2. Redesigned C-DQ: (a) Member identification design. (b) Nominal C-DQs (Place Types) present options hierarchically. A user can toggle between a default view (left) and summary view (right). (c) Group members can send or receive pings to ask others to agree on a specific option. (d) Ordinal C-DQ with a red box which indicates no consensus is made on Price Range. (e) Quantitative C-DQ, Ratings.

- **Ping**: We devised *Pings*, a non-verbal communication mechanism embedded in C-DQ that could be used to expedite agreement on a preference option. Specifically, one group member can ask another to agree on an option using a button with a "poke" metaphor (see the top icon in Fig. 2 (c)). The receiver can then review the ping in her C-DQ (see the bottom in Fig. 2 (c)). A user can only send pings for preferences that she has agreed with others on. Our participants provided positive comments about the ping feature and we expect this mechanism could support quick and targeted communication without the need for additional text-based communication.
- **Visual affordance**: We found that users commonly wanted to focus on (1) options upon which everyone agreed or disagreed, and (2) the actions that they can trigger using C-DQ. To present clearer visual affordances, we color-encoded these two information types in the redesign. Specifically, we color-encoded options that are agreed upon by everyone (e.g., "Japanese" and "Bars" in Fig. 2 (b)) in green, and criteria without any agreement in red as shown in Fig. 2 (d). Next, we applied a purple color scheme for interactive features, such as check boxes, slider handles, and buttons for Ping.

The system Requirements for ComeTogether are as follows:

- **Repository**: Studies show that users view "found items" frequently in group web search tasks [51]. Our users mentioned that having the capability to add a place to a repository for a group or oneself helped them revisit possible candidates and eased their decision-making efforts. In ComeTogether, we present these features when a user sees the detailed view of a location (see "Add to Group Picks" and "Add to Personal Favorites" buttons in Fig. 1).
- **Voting**: Voting is widely used in social tools to support group decision-making [47]. Users mentioned that having an explicit way for confirming a place could make communication more efficient and the coordination outcomes seem more fair. Based on findings in our formative study, we present unanimity votes over plurality votes in ComeTogether (see "Start Voting to Confirm" button in Fig. 1).
- **Tracking issues & contributions**: During the design process, we discovered a need to help users keep track of event progress. These needs were particularly imperative in asynchronous scenarios. Consequently, ComeTogether sends emails to the group when (1) someone joins the event, (2) one is mentioned in a chat, (3) one receives a ping, (4) someone initiates a vote,

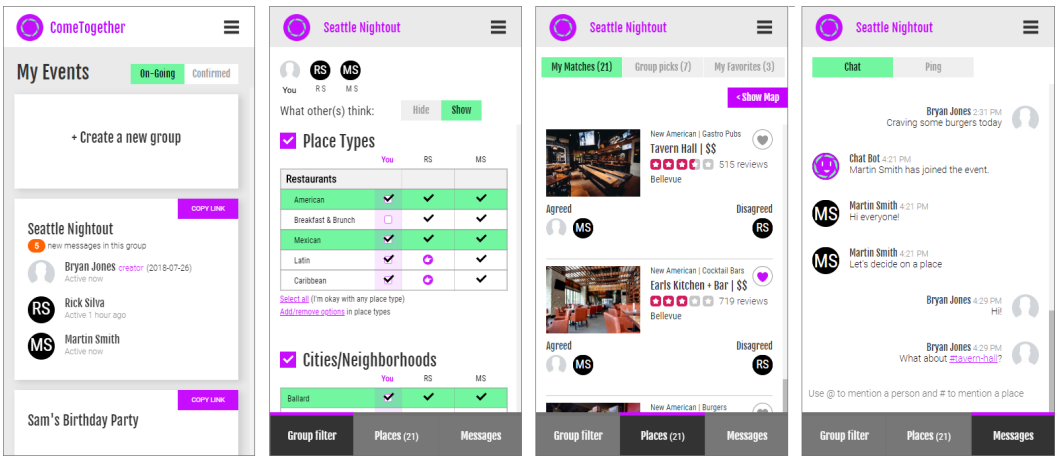

Fig. 3. Mobile screens of ComeTogether, from the left: Dashboard, C-DQs, List, and chat.

or (5) the group confirms a place through a vote. In addition, ComeTogether uses a chatbot that reports when someone (6) adds a place to a group pick or (7) modifies C-DQ options.

- **Mobile**: Many participants mentioned that they wanted to use ComeTogether on mobile devices. Recent studies suggest mobile local searches are often undertaken in a social setting [50], but few systems support collaborative information-seeking on mobile devices [11]. We built a mobile version of ComeTogether with three tabs, "Filter," "Lis,." and "Chat" at the bottom. See screens in Fig. 3.
- **Miscellaneous**: Our users indicated a preference for one click log-in through Facebook, separating on-going and confirmed events in the dashboard, and a "lightweight" event time setting (i.e., support changing event times anytime).

4.2 Methodology

In S2, we deployed ComeTogether for 4 weeks to understand how using ComeTogether can play a role in people's CIS practices when coordinating their social events. In S2, every participant went through an onboarding online chat, weekly diary-survey, and a final interview, similar to S1.

We used the onboarding chat to introduce core features of ComeTogether and to help participants understand the process of the study. They were told that they could freely invite their friends to use ComeTogether for coordinating their upcoming social events. If they did not find using ComeTogether useful, there was no need to use it at all, but they would still be invited for the final interview. This instruction is similar to prior work [11, 27]. Participants were not given any tasks or scenarios to use ComeTogether and were free to use or not use the system for any purpose.

Once the participants started using ComeTogether, they set automatic weekly reminders of the diary using their calendar applications during the study period. We logged participants' behavior that showed how they used ComeTogether. In collecting the log, we replaced all identifiable information such as their name with random words (e.g., "Penguin"). In the final interviews, we asked questions based on their diary entries, and had them walk us through their individual experiences each day to understand how ComeTogether was used in each instance. In total, we had two sets of data to draw our findings.

- **Behavior logs**: We measured participants' use of ComeTogether per day (i.e., the number of users logged-in and number of events created/ confirmed), and per event (i.e., the number of opening place details, using ping, chatting, and voting).
- **Final interviews**: After 4 weeks of deployment, we asked participants about their experiences using ComeTogether, including what they liked and disliked about the experience, their uses of specific interface components such as C-DQ, ping, voting, and chat. We also had them compare their experiences as an organizer or as an invitee while using ComeTogether.

The behavior logs and interview data was analyzed in the same way as in S1. Together, these two analyses complement each other and offer a comprehensive view of the participants' experiences with ComeTogether.

Participants were recruited using the same methods and criteria as S1. However, we encouraged participants to sign up in groups to reduce the potential barrier to using a novel system. Initially, there were 7 groups with 15 participants (3 pairs, each group of 3 and 4, and 2 individuals). Each group was composed of already established friends (except 2 individual participants). There were 9 females, 6 males, and their age groups were 18-24 (60%) and 25-34 (40%) years-old. Over the study period, our 15 participants invited 23 new individuals (in total, 38 individuals) to use ComeTogether. However, due to various constraints, we did not include these auxiliary users in analyzing our data set, so the findings we present next are the themes that emerged from our initial 15 participants' experiences. We compensated our participants based on the following criteria:

- For each week, each participant would receive $10 if (s)he either (1) created and invited friends or (2) joined an event created by others and a group confirmed the event. (S)he could thus receive up to $40 over 4 weeks.
- Each participant would get $30 if (1) (s)he submitted weekly surveys if (s)he used ComeTogether and (2) did a 1-hour online closing interview.

Participants' compensation ranged from $40 to $70. On average, 15 participants received $60 (SD=10). We note that we carefully chose the amount of weekly compensation ($10) so that it would not be so large that it would coerce the participant's experiences with ComeTogether, but also not so small that it would demotivate them in maintaining their participation over 4 weeks.

4.3 Results

In our S2 results, we describe how participants used ComeTogether and in what ways the system supported their CIS for social event coordination. Specifically, we present a descriptive analysis of the behavior logs and then layout the major themes that emerged through our qualitative analysis.

4.3.1 Overview of ComeTogether Use. Over 4 weeks, 15 participants were involved in coordinating about 4 events per person (SD= 1.6), by creating 1.6 events (SD= 1.5) or joining as an invitee 2.5 events (SD = 1.8) on average. A total of 27 events were created and 21 of those were confirmed through a vote. The planning duration of the 21 confirmed events ranged from a minimum of 2.3 minutes to a maximum of 6.2 days (M= 29.3 hrs, SD= 47.3). The group size of the 27 events varied between 2 and 5 (M = 2.8, SD= 1.0). Participants interacted with ComeTogether 48.2 times on average for seeking information (i.e., the interaction types for using C-DQ: changing C-DQ: M = 34.7, SD = 28.8 and opening place details: M = 13.5, SD= 14.8), and used features related to decision-making 10.2 times (the interaction types for suggesting a place to Group Pick: M = 6.0 SD = 7.3, Ping: M = 0.9, SD = 1.8, chat: M = 1.7, SD = 1.8, and voting: M= 1.7, SD= 1.3).

4.3.2 Distributed Seeking Efforts, Blurred Role Boundaries. We found that using C-DQ helped participants distribute their effort in performing CIS while coordinating their social events. Such distributed seeking effort created a blurred line between the role of event organizer and invitee. P11 said, "*it didn't feel like there was an organizer and invitee. It felt like we all had kind of planned it or decided on it together.*" When the participants organized an event through ComeTogether, they felt less burden as an organizer than participants in S1 who used interfaces based on individualized designs. P7 said, "*I never felt that as an organizer, I was doing way more than, as a person creating the event, as a person responding. I never felt like it was more. Well, I do organize another event outside of the website, it felt a lot more on me to try and get everyone together.*" In fact, from the log data, we found that the average information seeking behavior frequency (times that each user interacted with handles in C-DQ) for event organizers was 10.2 times while the invitees sought information for 10.5 times on average, indicating that there was no difference in effort between organizers and invitees in their CIS.

Participants indicated that using ComeTogether allowed everyone in a group to have a voice in deciding where to go, which helped relieve the tensions of different expectations between organizers and invitees that we observed in S1. For example, P15 appreciated being able to express opinions as an invitee: "*[ComeTogether] allows you to just have a lot of options available to you, versus [communicating] in person or text when someone [an organizer of events] is sort of telling you . . . and then you're like, Okay, even if you had laid out a bunch of options.*" This, in turn, helped organizers feel more confident about their choices. P13 stated that ComeTogether provided an "*explicit way for people to tell you what they like and what they don't like . . . 'Cause I'm so worried about ignoring others' voices.'*" P3 shared a similar sentiment: "*[What I am] Not comfortable about*

Yelp is . . . to show to my friends hey, what do you think about this? . . . But [the] good thing about this one [ComeTogether] is that . . . ***I*** *can select what kinds of stuff that* ***I*** *want to eat like Korean food or Japanese food.*"

The voting feature helped the participants engaged in CIS to see group decisions as fair. P5, for example, liked the voting feature because "*it felt more democratic, in the sense that everyone had a chance to input their reasoning, or input their preference.*" She added, "*In the past when we've tried to organize events it's mainly through that Facebook chat and then often everyone shoots out ideas, nothing gets decided, and then it just kind of passes. So, with Come Together . . . it's more organized. Then everyone has to do their part so then a decision can be reached easier.*" P14 compared the voting feature to "*a receipt of our decision making.*" P6 shared a similar sentiment "*it helped us cement the decision of where we were going together.*"

In summary, participants reported that ComeTogether distributed individual efforts during the group decision-making process, and blurred the boundary between people's perceived roles as an organizer or an invitee. They noted that the system benefited not only event organizers but also invitees, collectively making group decisions more fair.

4.3.3 Increased Awareness, Increased Mutual Understanding. Many participants noted that C-DQ's main strength is that it allowed them to explicitly see others' preferences. By using C-DQ, they did not need to "ask" around much, because they were "seeing" what others preferred (P6). This ability led to increased awareness of others, which helped the group to be more transparent and collaborative in their social coordination process. As participants came to know what their friends wanted, they were likely to behave prosocially to achieve group harmony. P10 said, "*I* ***have to*** *be mindful of other people's preferences and make sure I'm not the outlier, so I* ***had to*** *be cognizant of that as well.*" P5 explained how he incorporated friends' preferences in making his decision: "*the things [to my friends] that are more important are the types of restaurants and price point . . . [so] I'll weigh [them] a little more in my decision.*" C-DQ also helped with recalling others' preferences in the future when making suggestions for places to visit, such as remembering that someone likes or dislikes a specific cuisine (P8). Furthermore, seeing others' preferences also benefited participants who were unsure of what to select by providing them with a common ground to start with: "*when one of us was talking it out, like, I want Caribbean, I want this, . . . then that made me think, Oh, I actually want that stuff [what her friend's picked], too*" (P14). C-DQ thus helped increase mutual understanding while collaboratively searching information for a group decision.

However, this level of awareness might not be always desirable–we also found that "seeing" other's preferences could create potential tensions. For example, P15 shared a moment when she felt pressured because her friends had already agreed on a certain option in ComeTogether: "*I see that three of the people have all chosen Mexican, but I don't want Mexican, [so] I would feel bad, and I'd be like, 'Alright, I'm just gonna choose Mexican, even though it's not really something that I want.'*" P11 also reported a time in which he changed his own filter to indicate a different preference after seeing those of others: "*Seeing if they had narrowed it down made me wanna narrow it down even more. Just to help us get to the right answer . . . it's like you were filtering in order to create a more manageable list. More so than you were actually opposed to going to that place.*" Additionally, some participants desired more privacy for sensitive criteria, such as price range, when they were on a budget (P8, P10). These concerns may vary according to the pre-existing social dynamics of a group, which may be why some participants did not mind sharing their preferences about price ranges when working with a group of close friends (P3, P9). Despite these social considerations, participants generally agreed that "seeing" other's preference helped their CIS to be more transparent in group decision-making processes.

4.3.4 Easier CIS, Efficient Group Decision-Making. Participants said that ComeTogether made CIS easier, which enabled their group decision-making process to be more efficient. Seeing others' preferences in C-DQ also relieved the burdens of group communication. P8 noted, "*since we can directly see what other people's preferences are . . . we don't have to talk, like go back and forth to see if this is a place that you want. So by using ComeTogether, it's more open . . . more direct.*" She added, using "*traditional ways*" for CIS "*you might need to email each other back and forth to negotiate on a place, but using the [C-DQ] filters . . . you just need to select your own preferences, and the system will give you a list that everyone agrees on. So I think that shortens the, I don't know, the time cost.*" Some participants also remarked on the benefits of an all-in-one tool for the entire social coordination process. P2 did not need to move back and forth among multiple tools, because ComeTogether kept her group's effort "*all one place, instead of having to go to Yelp then have to bounce around between looking at a [Google] map.*"

Further, participants found that the ping feature was beneficial in making CIS and group decisions more efficient. P13 used the ping as "*a friendly way to remind people that there's a decision to be made.*" He liked how simple ping is to use as a reminder, "*It just seems like the perfect level of 'Your attention please,' so I was really comfortable using that. Usually when I send out a nag email to somebody, waiting a certain amount of time, and really wondering if it's worth it.*" P7 also used ping as a quick nudge: "*It's just useful to be able to specifically tell someone a really quick, 'oh, would you mind changing this one thing or that' as opposed to having to just type out in the whole group chat or send a message on a text message or something.*" Participants noted that ping might be further useful for groups of people who are not close to each other yet, though that was not completely clear. P8 said, "*maybe ping works better for not so familiar groups, because it's kind of an official [way] to remind other people. But if you use chat feature with strangers or acquaintances you're not very familiar with, maybe it's a little bit awkward.*"

In the initial stage of CIS, while people are brainstorming about where to go, participants viewed a list of places, filtered by everyone's preferences, which enabled them to easily initiate their conversation. P12 noted: "*None of us are really that picky. Actually [we were] . . . indecisive to the point where they're like, 'Okay you choose, no you choose, no you choose. . . . it's not that people are rejecting, it's that they're so open minded . . . But no one wants to take the first step to just say something. For the app [ComeTogether], everyone's just so ready to just say, "Okay." Someone has to start it and then we'll all say okay.*" P10 liked how one's preference are instantly reflected on the map-view: "*with a lot of other . . . applications [where] we were searching by location, you have to drag and pull the map and everything and this would update in real-time. But having the checkboxes of the neighborhood was really convenient.*" Although speculative, some participants mentioned they feel ComeTogether would be more useful as the group size grows. P3 noted: "*The good thing about this is when there are many people, [ComeTogether would help coordinating events] much quicker ... [when there is] a large number of people in a group, the organizer cannot tell each person hey, you haven't done, done, done, done.*"

4.3.5 Discovering New Places, Learning about Friends. Participants reported that ComeTogether presented opportunities to discover something new about their friends or neighborhoods. While scrolling through the list of local places using ComeTogether, participants found new places where they could potentially visit. P11 said, "*it just encouraged me to find new places to eat, I think. Like having a whole list of the places downtown, like it reminded me of all the places I wanted to try, so that was good.*" Similarly, P6 observed, "*it helps me try out new things that I wouldn't have otherwise thought of, and more willing to push my outer limits because I saw that they did.*" In particular, these places are already filtered to meet one's preferences, so participants found it convenient: "*there's*

just so many restaurants and it's also personalized to you rather than to a group so I think that was super helpful . . . It matched our overall wants" (P14).

What participants learn about while using ComeTogether was not only places âĂŞ they also learned about their friends. P3 said, for example, "*It was kind of fun experience honestly because I could see what my friends don't eat and what their price range [is].*" P1 also said that she had never talked with her friends about what kinds of food they like. So she newly learned that her friend like Caribbean cuisine while using ComeTogether. Participants thought ComeTogether would be particularly useful for groups of people who are not familiar with one another yet like co-workers. Interacting through the system presented learning opportunities that might be helpful when developing social relationships: "*people aren't always super close as co-workers [so] Let's go eat. Then [ComeTogether] would be helpful"* (P12). For the same reason, P15 thought ComeTogether could be a modest way of communication channel: "*it'd make me more inclined to meet with somebody if I wasn't that close with them...it's just not as aggressive way of asking someone to go out to lunch or something, if you get a text from someone about lunch, it would seem like you have to answer them, you have to think about the wording, or whatever. But over here it's just like, 'Okay, you can suggest another place, or you can...' It's just little ways of letting the person know that you're open to it or not open to it.*"

4.4 Discussion

In S1, we discussed how when members of a group use interfaces based on single-user designs to perform CIS, they encounter user-side challenges leading to inefficient coordination efforts. In this section, we discuss how ComeTogether with augmented group awareness using C-DQ can ease the challenges we observed in S1, and how such improvement affected people's practice while engaged in CIS for their social event coordination.

Group dynamics based on perceived role: In S1, we observed clear attitudinal differences related to each member's perceived role–either as an organizer (more motivated for CIS) or as an invitee (more passive during CIS). We found the boundary between the two roles was blurred while using ComeTogether in S2. This difference can be attributed–in part–to the system allowing people to almost effortlessly initiate information-seeking using C-DQ. Once a member initiated seeking by choosing preferences, the indicated preferences were shared with others, triggering others to initiate their own seeking behaviors through C-DQ. As a consequence, the effort of information-seeking was more evenly distributed across the group, leading to perceptions that the work was more fairly distributed and they were more on board with the activities related to CIS.

Shared schemas in CIS: In S1, we found some individuals were more dedicated to seeking places than others. When they were done seeking, they shared the outcome as a suggestion to the group but often needed to put additional effort into explaining the reason(s) for their suggestion. We assumed seeking information using the single-user design limited their ability to share their thoughts to the others, meaning that each seeker had to build their own schema without referring to others. In S2, we observed that people were mindful of others' thoughts at the same time that they interacted with C-DQ. We see this facilitates a group's shared schemas, contributing to improved mutual understanding. In other words, C-DQ appeared to enable shared schemas.

In CSCW, many studies support the notion of shared schemas in the domain of search interfaces [38]. We briefly discuss the major distinctions between using a search interface and Dynamic Queries (DQ). Searches using keywords supports highly specific and flexible capabilities in information-seeking. However, due to their specificity, keywords often encode some private context or intention that is not meant to be shared with others during CIS. For example, Aldosari found that participants often felt that sharing their search keywords with others was 'awkward' in the context of collaborative place-seeking [4]. Because C-DQ is designed to use preference ranges rather than keywords,

CIS Activities			Information-seeking	Decision-making
S1	Member's perception	Organizer	More motivated for seeking, but hard to elicit preferences from group members	Suggestion for making an agreement
		Invitee	Chime-in later; difficult to represent preferences	Listen and respond to agree/disagree
	Possible effect of using single-user designs		• Different expectations between role lead to disparities in seeking effort • Hard to know others' preferences (decentralized schemas)	• Increased cost of communication for building common-ground and for decision-making
S2	Member's perception		Blurred role boundary between an organizer and an invitee while seeking	Everyone on-board for making a decision
	Possible effect of using ComeTogether		• Distributed seeking effort • Increase shared understanding (synchronized schemas)	• Efficient communication for decision-making
			• Make CIS Inclusive • Discovering new places	

Table 2. Participants' perceptions of their CIS process: before (upper row, S1) and after (lower row, S2) using ComeTogether

the interface necessarily exposed less specific detail about the users. During S2, we thus found that in general, participants were not reluctant to share their preferences. To support shared schemas among people engaged in CIS, designers should understand the tradeoff between specificity and privacy that the two interface types imply. Another distinction between the two is the use-context. Often, people use search keywords for finding something they already know about [51], while DQ is preferable for finding and filtering out irrelevant candidates during exploration of the target information space [3]. In the case where the seekers are open to new, unknown places, DQ offers a better capability than a traditional keyword search interface, which we found when people said C-DQ helped them identify and explore new places. In supporting shared schemas, we assume the considering the strengths and weaknesses of both interfaces would be critical for building a tool that can lead to successful CIS.

Reduced cost of communication for consensus-building and decision-making: In S1, we found that groups often faced difficulties in reaching to a decision. Seekers tended to be active, while the rest of the group tended to be passive when forming an agreement. In S2, we heard from participants using C-DQ that they were able to make decisions that they felt were fair, transparent, and inclusive without much discussion. The shared schemas these groups experienced while seeking information reduced the cost of communication while still yielding desired results.

Through S2, we found that the previous *lessons* in CIS [58] hold in place-seeking for social event coordination scenarios: (1) Encourage each member to make their own contribution, and (2) provide effective ways for the members to communicate with each other to lessen the group's coordination cost for requesting information, and (3) offer mechanisms that let participants not only explore their individual differences but also to negotiate roles and responsibilities. Doing so will allow each member's actions to flow and yield successful collaborative outcomes. The major differences we observed between S1 and S2 are described in Table 2.

5 IMPLICATIONS FOR DESIGN

In this section, we distill the findings in S1, S2, and related ideas from CSCW literature to offer five design considerations (DCs) that researchers and/or practitioners could apply when adopting C-DQ for building groupware. For some DCs, we discuss new research/design opportunities that could endow transparent, efficient, friendly, and communicative CIS experiences to users. We then discuss the lessons we learned through our work.

DC1. When to use C-DQ: Applying C-DQ can lead to a successful or unsuccessful CIS. Based on our findings, using C-DQ is likely to be effective for facilitating CIS when (1) people have little knowledge about the information space they are attempting to seek, (2) people are motivated to try something new and unfamiliar, and (3) considering everyone's preferences matters. Conversely, C-DQ may not be useful when (1) people know a lot about the information space, (2) a group's division of roles is clear (i.e., people expect that seeking information is a particular person's duty and not that of others), and (3) group power dynamics make some opinions more important than others' (e.g., an expert vs beginners, a boss and subordinates).

DC2. Adopting C-DQ in existing applications: C-DQ is used as a sub-component in ComeTogether, a dedicated system for supporting social event coordination. Alternatively, C-DQ can also be used as a glue component to information-seeking technologies as suggested in previous findings [50]. In adopting C-DQ to existing applications or services, we anticipate that there are two cases that will improve CIS. The first case is to embed C-DQ into a text messenger (e.g., Google Hangout, Facebook messenger). S2 results show that the text messenger component in ComeTogether was rarely used, as participants already had their own group chat room established in a different text messenger. C-DQ could be included as an add-on in an existing messenger as most modern text messengers allow for add-on functionality. Secondly, C-DQ can be embedded in dedicated destination recommendation systems (e.g., Yelp, Airbnb), and e-commerce services (e.g., Amazon, eBay). We envision that both of these cases could present promising research opportunities and would likely improve a group's experiences when engaged in CIS.

DC3. Privacy Consideration: Although participants felt that the group awareness provided by C-DQ was useful, occasionally people wanted to hide their preferences from the group. Privacy has long been a critical issue in designing groupware in CSCW [2]. The privacy tensions we observed are related to the three theoretical viewpoints of privacy that Moor discusses [49]: a) *What to share with others*: theories related to non-intrusion (into one's space), b) *What to see from others*: theories related to non-interference (with one's decision), and c) *Having control over what to share and what to see* - informational privacy. Future C-DQ designs must strike a balance between task-efficiency and group member privacy so that we can understand how awareness can integrated into the design to complement the theoretical perspectives above (see also Pötzsch [54]). One potential way to achieve informational privacy in using C-DQ is to adopt Teevan et al.'s proposal to allow users to switch modes between individual information-seeking and CIS by toggling on-and-off the group awareness presented in C-DQ [62]. With such switching, we anticipate the utmost important design consideration would be to give individuals control over mode switching or force the group to use the same mode all the time.

DC4. Device Consideration: Aldosari found no significant differences between the usage of a mobile and desktop platform in performing CIS [4]. Device-specific features can improve the experience of C-DQ. In designing device specific features, the following factors could open research opportunities. On mobile, GPS could offer a variety of location-based services. Such capabilities could lead to novel applications of C-DQ, such as filtering places based on mutual physical distance or travel times to a place, which can be important information in an information seeking effort [30, 32]. As for desktop devices, we found that people's needs for criteria were much more diverse

than we initially expected when designing ComeTogether. In the case of supporting a place-finding scenario, allowing filtering of places through a menu or availability for reserving a table at a given time could support interesting user scenarios. Desktop devices enable advanced selecting, drawing, and moving of points, lines, and polygons. Leveraging such capability, C-DQ can offer better CIS environment for selecting, manipulating, and sharing criteria and ranges. For instance, a member's selection a certain point in an image may extract contextual information and convert that to decision criteria and ranges (e.g., matte screen, red t-shirt). Such capability can be also very valuable for devising spatial interaction related to CIS.

DC5. Automation vs. Control in C-DQ: While C-DQ can make CIS more inclusive, users can still suffer from the overhead of managing many available criteria and options per each criterion. To reduce the effort required for choosing and indicating diverse preference types using C-DQ, we think that implementing intelligent suggestions for each user's criteria-of-interest and/or initial range could reduce their effort. There has long been a debate about the tradeoffs between automation and controllability in HCI and related communities, focusing on how the automation gained by intelligent features in a system can negatively impact people's perceived controllability, or vice versa. Surprisingly, Quentin et al. found there is no solid research to date that investigates such a trade-off [55]. Understanding which features in C-DQ can be automated and which features in C-DQ can be presented as controllable needs to be studied. Such automation features can be applied in, for instance, chat-message-driven (i.e., using messages for criteria selection) or history-driven criteria selection for applying techniques in collaborative filtering (e.g., [26]).

DC6. Use context Consideration: We deployed C-DQ in a casual use context where participants coordinated their social events with their friends. When considering more crucial scenarios, such as a group of professionals seeking a place for a new company branch or a family purchasing a home, we assume additional features for resolving surfaced disagreement can be useful. Also, applying C-DQ to special user groups, such as children [27, 28], gamers [42], or co-editors [36] may need formative need-finding process for deriving more targeted design considerations.

6 LIMITATIONS

Our studies addressed only the scenario in which a group seeks a place while coordinating a social event. Applying C-DQ using other design considerations may help researchers and practitioners adjust designs to build other tools. However, applying DCs to additional scenarios not covered in this work should be pursued with care. We thus discuss limitations of our studies.

- **Sample size**: S2 results use 27 created events of which 21 were confirmed. Further observation with more sample groups may be required for a broader generalizability.
- **Study place, period, and characteristics of participants**: We deployed ComeTogether on one metropolitan area in US for four weeks. Most of our participants were younger than 30. Patterns of using C-DQ may vary depending on how long they were exposed to C-DQ and/or characteristics of groups, such as location and age.
- **Characteristics of groups**: Most of our groups characterized themselves as close friends and/or schoolmates. However, patterns of using C-DQ may vary depending on group types (e.g., coworker, distant friends, family) and years of friendship.
- **Degree of complexity**: We didn't measure each participant's perceived degree of complexity required for coordinating for each event. Further studies are needed to understand how the perceived degree of complexity might change the ways the groups interact with C-DQ.

7 CONCLUSION

Our overarching vision for this work was to gain deeper insights into the challenges that a group encounters during CIS because they relied on tools based on single-user design, and to understand how we could redesign such experiences with a new tool that explicitly supports the best forms of group interaction techniques known to the CSCW community. We believe our findings show how the current interfaces designed for CIS can evolve to reshape people's experiences when engaged in CIS and benefit them in situ.

AUTHORS' CONTRIBUTION

Sungsoo (Ray) Hong was responsible for defining the intellectual framework of this work. This includes defining the problem space of this work based on existing literature in CIS and group decision-making, working with co-authors to design and conduct S1 and S2, creating and stabilizing ComeTogether, determining implications for design after the studies, and writing the manuscript. Minhyang (Mia) Suh significantly contributed to understanding users' common challenges in CIS and effect of ComeTogether. This includes the design of the research methodology of S1 and S2, organizing participants, and identifying the main findings of S1 and S2 with other authors. Taesoo Kim greately contributed to building ComeTogether in both front-end and back-end sides. Irina Smoke, Sangwha Sien, and Janet Ng substantially contributed to this work in data collection processes of S1 and S2. This includes conducting closing interviews of the two studies and performing quantitative and qualitative analyses of interview transcriptions, surveys, and log data. Finally, Mark Zachry and Juho Kim significantly contributed to building the intellectual framework of this work with every author. Especially, Juho Kim served as a corresponding author of this work. The address of ComeTogether used in S2 is: https://cometogether.cool

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