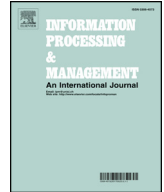




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## Querytogether: Enabling entity-centric exploration in multi-device collaborative search

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### ABSTRACT

Collaborative and co-located information access is becoming increasingly common. However, fairly little attention has been devoted to the design of ubiquitous computing approaches for spontaneous exploration of large information spaces enabling co-located collaboration. We investigate whether an entity-based user interface provides a solution to support co-located search on heterogeneous devices. We present the design and implementation of QueryTogether, a multi-device collaborative search tool through which entities such as people, documents, and keywords can be used to compose queries that can be shared to a public screen or specific users with easy touch enabled interaction. We conducted mixed-methods user experiments with twenty seven participants (nine groups of three people), to compare the collaborative search with QueryTogether to a baseline adopting established search and collaboration interfaces. Results show that QueryTogether led to more balanced contribution and search engagement. While the overall s-recall in search was similar, in the QueryTogether condition participants found most of the relevant results earlier in the tasks, and for more than half of the queries avoided text entry by manipulating recommended entities. The video analysis demonstrated a more consistent common ground through increased attention to the common screen, and more transitions between collaboration styles. Therefore, this provided a better fit for the spontaneity of ubiquitous scenarios. QueryTogether and the corresponding study demonstrate the importance of entity based interfaces to improve collaboration by facilitating balanced participation, flexibility of collaboration styles and social processing of search entities across conversation and devices. The findings promote a vision of collaborative search support in spontaneous and ubiquitous multi-device settings, and better linking of conversation objects to searchable entities.

### 1. Introduction

The impact of search on our everyday lives is unparalleled. Yet, surprisingly, search is often thought of as a solitary user activity, focusing on eliciting a user's information needs and improving search-result relevance. Recently, increasing attention has been devoted to search as a collaborative activity that is often co-located, spontaneous and initiated informally from a dialogue (Brown, McGregor, & McMillan, 2015; Morris, Fisher, & Wigdor, 2010a). Users are inspired or informed by others' searches, and can distribute search efforts, exploring the information space in parallel. Despite the increasing number of situations in which several co-located people engage in collaborative search, available devices and public screens are not effectively used for synchronous collaboration.

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Situations addressed by existing collaborative search systems include distributed users on mobile interfaces, or co-located interaction on tabletops. We wanted to focus on a common ubiquitous computing scenario in which several co-located users spontaneously engage in collaborative search, using personal devices as well as available large screens or projectors. In particular, we investigate what user interfaces and search systems facilitate collaboration across such devices.

Several collaborative search systems have been proposed (Table 1), supporting either distributed collaboration (Halvey, Vallet, Hannah, Feng, & Jose, 2010; Morris & Horvitz, 2007; Paul & Morris, 2009; Wiltse & Nichols, 2009), or co-located search situations (Amershi & Morris, 2008; Chung, North, Self, Chu, & Quek, 2014; Golovchinsky, Adcock, Pickens, Qvarfordt, & Back, 2008; Jetter, Gerken, Zöllner, Reiterer, & Milic-Frayling, 2011; Morris, Lombardo, & Wigdor, 2010b; Morris, Paepcke, & Winograd, 2006; Teevan, Morris, & Azenkot, 2014). Collaborative search systems have targeted different kind of devices and their typical features include support for result sharing and coordination of work. Moreover, methods and tools supporting these activities continue to be general-purpose communication systems, such as email or instant-messaging systems (Morris, 2008) or, in co-located situations, face-to-face communication. Conversely, support for exploratory search in collaborative situations has remained largely unaddressed (Hearst, 2014). We maintain that the problem of ubiquitous co-located search should be targeted as a new design problem that considers a range of devices, including smartphones, tablets, laptops, and larger public screens utilized simultaneously in the same environment. In this context, user interface concepts need to consider the opportunities provided by multitouch interaction in manipulating information directly as well as constraints, such as the limited possibility of text entry on different devices.

The main research question that we investigate is whether an entity-based user interface (Klouche et al., 2015) provides a solution to support co-located search on heterogeneous devices. Such interfaces have only been investigated in search systems tailored to individual users, especially to facilitate exploration on touch devices without a physical keyboard. How they affect collaborative search is still unknown. Entity search, recently adopted in Web-wide knowledge graphs, is an opportunity to move search from keyword-based text queries on unstructured data, toward semantic search that recognizes how text refers to different types of things, such as people, places, organizations, etc. Similarly, a user interface that allows queries and results to be formulated using entities provides information that can be manipulated in an intuitive way and might be better suited for mediated interaction between people. Recent studies on collaborative search demonstrate how it is often co-located, spontaneous and initiated informally from a dialogue (Brown et al., 2015; Morris et al., 2010a), such that search should integrate with the conversational context identifying “searchable objects.” Ideally, in the future, any entity mentioned in a conversation will be searchable (Andolina et al., 2018; Brown et al., 2015; Shiga, Joho, Blanco, Trippas, & Sanderson, 2017). While the query-and-response paradigm, with long lists of document-based results, works well for individual look up search, it falls short in exploratory and mobile scenarios (Klouche et al., 2015). As in the latter cases, we posit that entity-based interfaces effectively support collaborative search in ubiquitous settings. We start by analyzing the state of the art of collaborative search situations and tools to understand current trends and needs in collaborative search and devise general design goals for our system.

We present the design and implementation of QueryTogether (Fig. 1), a collaborative search system designed for co-located exploratory search in which two or more physically co-located users search together supported by entity-centric recommendations. QueryTogether was deployed in a multi-device collaborative environment with tablets and large screens, and evaluated in a collaborative exploratory search study with nine groups, each consisting of three people. Conventional laptops and large screens, with more traditional search tools based on queries and lists were used as a baseline for comparison. The study’s goal was to evaluate QueryTogether and understand how its novel design, including explicit support of exploration through entity-centric recommendations, affects collaborative search in terms of exploration support, collaboration, and engagement. The results show that, relative to the baseline, QueryTogether leads to significantly improved contribution balance and search engagement without compromising effectiveness. Interaction analyses also suggest that QueryTogether led to more effective usage of the heterogeneous devices together with improved support for diverse collaboration styles and common ground establishment.

## 2. Background

Collaborative search is increasingly documented as an activity that initiates spontaneously as part of co-located social interactions (Brown et al., 2015; Morris et al., 2010a). Informal opportunistic interactions among colleagues, for example, often happen by chance in common areas or cafeterias, and they may lead to conversations that end up being critical to a project’s success (Isaacs, Tang, & Morris, 1996; Kraut & Streeter, 1995). As part of such conversations, people may spontaneously turn to their personal devices to collaborative search for information (Brown et al., 2015) that may or may not be familiar (Hearst, 2014). However, the systems designed to support collaborative search, until now, have focused mainly on increasing awareness of search activity and division of labor across collaborators (Morris & Horvitz, 2007; Zhang et al., 2017), leaving other important aspects of collaborative search less investigated.

Table 1 summarizes several attempts to create collaborative-search support varying from conventional distributed Web-search extensions to domain-specific tabletop designs. SearchTogether (Morris & Horvitz, 2007) facilitates remote collaboration by supporting awareness, division of labor, and persistence. ViGOR (Halvey et al., 2010) uses similar principles but in the multimedia domain. MUSE (Krishnappa, 2005) allows pairs of remote users to search for medical information. CoSense (Paul & Morris, 2009) supports remote collaborative search by focusing on sense-making and providing several rich, interactive views of users’ search activities. CollabSearch (Yue, Han, He, & Jiang, 2014) is a Web search system where collaborators can save Web pages or snippets and make comments. Similarly, Coagmento (Shah, 2010) provides integrated support for communication, note-taking, and the collection of text snippets or other objects from Webpages. ResultSpace (Capra et al., 2012) provides awareness of the group activity by displaying query histories. It also supports the rating of query results and includes filtering controls based on ratings from

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