CoFind: A Browser Plugin for Investigating Co-located Collaborative Web Search

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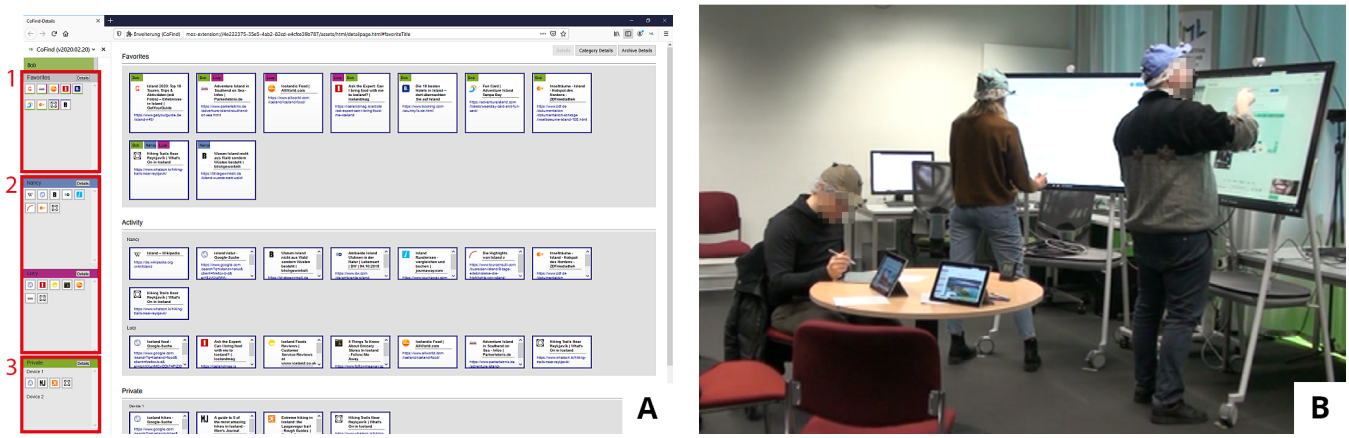

Figure 1: (A) Screenshot of the *CoFind* browser plugin, showing the sidebar component on the left side (1: group space, 2: activity space, 3: private space) and the landing page with shared information in the active tab, (B) Experimental setup of a co-located collaborative search scenario with tablets as personal search devices and large displays as shared devices

ABSTRACT

Group awareness is a prominent challenge in the field of co-located collaboration in Multi-display Environments (MDE), where several personal and shared devices are operated simultaneously by multiple users. With a focus on Collaborative Information Seeking (CIS) and particularly different levels of information sharing, our overall goal is to investigate aspects that influence this group awareness as well as the general group performance in such MDE. In this work, we present the conceptual foundation and approach of a research tool, called *CoFind*. Developed as a lightweight web browser plugin, which connects collaborators by sharing information resources, it provides comprehensive data and activity logging in the context of user studies and their evaluation. Based on an initial lab experiment, we also present first insights on the feasibility of our approach and the utility of our developed tool, allowing to plan and carry out further user studies in this challenging research field.

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CCS CONCEPTS

• **Information systems** → **Collaborative search**; *Search interfaces*; • **Human-centered computing** → *User studies*; *Collaborative interaction.*

KEYWORDS

collaborative information seeking, awareness, web search

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1 INTRODUCTION

Collaboration in co-located working places is assumed to be very productive in terms of direct communication, physical and social interaction. This can even be strengthened by providing appropriate technical equipment, e. g., personal display devices to work simultaneously (division of labor) and large interactive displays to easily share, merge and discuss content. Such *Multi-display Environments* (MDE) are subject to extensive research, primarily from an interaction or user interface perspective (e. g., [2, 3, 5, 11, 23, 25]). However, in a collaborative MDE, where users can work both cooperatively and individually, new issues appear, which may affect

the group performance—first and foremost reduced awareness of other users' actions and activities, but also increased distraction (cf. group awareness [9, 10]). Additionally, information intensive tasks, like information retrieval or sense-making, impose further demands on teamwork, for instance, the definition and articulation of the (shared) information need, task delegation, assessment of quality, coverage, and authority of particular information resources, or discussion of relevance.

Due to the fact that a vast majority of today's information seeking activities are web searches [13], a number of approaches have been proposed to also support collaborative web search [4, 7, 13, 20]. In particular, most of these applications focus on *remote* collaboration. As a result, it remains an open research question, which remote techniques and mechanisms can or should be transferred to co-located settings [22].

At this intersection of MDE and *Collaborative Information Seeking* (CIS), we generally aim at improving our knowledge about group awareness: How can we foster it? Which aspects have an effect on it? Does awareness have a negative effect at some point? In this work, we present the conceptual foundation and approach of a research tool, called *CoFind*. Developed as a lightweight web browser plugin (Figure 1(A)), *CoFind* represents the technical basis for our on-going investigation of the aforementioned questions. Its main purpose is to provide basic means for conducting and observing synchronous, collaborative web search sessions. We furthermore report on a preliminary lab experiment carried out to assess both the feasibility of our general approach and the utility of our developed research prototype. Finally, we also reflect on implications of initial results of this experiment and discuss future research opportunities with regards to co-located collaborative information seeking in MDE.

2 RELATED WORK: TOOLS FOR COLLABORATIVE WEB SEARCH

In past years, several online tools have been presented to support and study group awareness in CIS. For instance, with SearchTogether [14] several functions have been introduced like a chat, query and search history, website recommendations and interface mediation. Various tools followed, like ResultsSpace [4], that provides a results list with an integrated voting mechanism, whereas Querium [7] focuses on multi-session search and provides faceted search. The Coagmento system [8] was developed as a browser plugin. It emphasized the need for shared information, e.g. web pages, but the sharing itself remained a manual process.

These tools are primarily built for remote collaboration. There are also tools for co-located collaboration, but they are either based on outdated technologies [1, 19], for specialized role-based scenarios [6] or using specialized hardware like tabletop displays [15]. Altogether, they do not utilize today's wide spread technologies like tablets and notebooks, nor do they consider the potential of multi-display environments. Furthermore, extensive evaluation and logging mechanisms of awareness criteria could be helpful to gain deeper knowledge of CIS processes, but are not supported by current tools. While the further development of Coagmento is heading in this direction [12, 24], supporting browser logging of individual or synchronously working groups, the tool is not designed for co-located CIS in a MDE, where users dynamically switch display devices or use multiple devices simultaneously.

3 INFORMATION SHARING IN CO-LOCATED COLLABORATIVE INFORMATION SEEKING

During co-located collaborative work, users may find it more difficult to concentrate on their work as the focus on the personal workspace can easily be affected by physical activities of others and group conversations. Appropriate technical support for workspace and group awareness, like unobtrusive sidebars and notifications, may help to compensate this issue. Thus, users are allowed to work individually and in parallel without being distracted, while being aware of what the other users have done or are doing. In the context of CIS tasks, a central awareness factor is the visibility and transparency of the (sets of) information resources that group members have collected or are currently working on. In collaborative web search sessions those information resources are web pages, sites or other online documents which users bookmark, tag or comment on. In order to investigate aspects of workspace awareness, it is worth thinking about *what, where, when and how* to share information resources in a more differentiated way.

3.1 Role of Information Sharing

According to our co-located multi-display web research scenario, sharing information should include what users are currently reading, what they already bookmarked, and how this contributes to the group task. In addition, information need to be distributed across devices, and individual as well as cooperative work shall be possible. In order to better understand information sharing in such settings and inform future design decisions, we discuss dimensions of information synchronization and sharing inspired by previous work [10, 16].

What *information is shared?* Assuming that shared information in a web-based CIS task are primarily online documents, we distinguish two categories: (1) retrieved and bookmarked web pages, tagged or annotated, (2) web pages currently opened in browser. For the second category we can distinguish (a) web pages currently viewed in an active browser tab, and (b) web pages currently open in background browser tabs. Furthermore, since users shall be able to operate multiple devices, it is also necessary to differentiate on which device the user currently views a web page and whether the device is actively used.

Where *is information shared?* Different variants of presenting shared information in MDE relate to general device roles: personal, shared, or multi-purpose displays. Therefore, shared information can be displayed in the following ways: (1) on all displays (broadcast), (2) only on shared devices, (3) only on personal devices, and (4) only on single personal device (if users operate multiple personal devices).

When *is information shared?* There are different strategies to trigger information sharing depending on how much synchronicity is desired: (1) *full synchronicity*, immediately with each user input, (2) *intervals*, fixed and recurring time periods (can be interpreted as sampling), (3) *pre-defined*, after specific events, e. g., bookmarking, opening a new tab, or (4) *commit*, upon user's explicit share command. Except to *full synchronicity*, this implies that there is

always a time span where changes made by a user remain invisible to group members until the next synchronization event.

***How** is information shared?* The way shared information is displayed and how users can interact with it is highly related to the *what* and *where* questions. With regards to visibility, comprehensiveness, and level of abstraction this dimension represents a challenging visualization task. Besides different display sizes and resolutions, shared information resources typically are multi-variate and come with rich meta (e. g., sources, timestamps, author and language information, content-based metrics such as number of words, user-related aspects such as visitor statistics). In general, the following approaches can be used for displaying shared information: (1) showing all available data, (2) showing selected aspects of resources, and (3) showing only a resource itself without additional context information.

These dimensions form a large range of possible combinations. Studies typically attempt to reduce or limit dimensions and variables to a manageable level. However, the *where* and *how* aspects are closely related, as the amount and complexity of shared information presentation is limited by the available display area and the need to avoid visual clutter and distraction. We believe that research in the advanced fields of Information Visualization and Cross-Device Interaction should be taken into account when designing the graphical user interface for shared information displays. Thus, in this early research phase we concentrate on the temporal (*when*) and the content-related dimension (*what*) to investigate co-located CIS in MDE. We also argue that *"when is information shared"* affects workspace awareness significantly and influences the speed and dynamics of a collaboration.

3.2 Potential Modes of Information Sharing

To investigate synchronicity and content-related aspects of information sharing, we identified three potential modes (Table 1) that combine selected parameters for comparative studies: *automatic*, *snapshot*, and *explicit*. In *automatic* mode, all necessary information including currently open tabs, bookmarks, and annotations (*what*) are shared instantly (*when*) with all group members. In *snapshot* mode, user define *when* to share content (*what*) using a dedicated commit button. Subsequent changes will remain private until the next "commit". In *explicit* mode, users define *when* and *what* information is shared by selecting specific subsets or single resources explicitly. This mode requires more activity from the user compared to the other two modes, since each single web page must be explicitly shared using a dedicated button. An overview of the modes and their properties is given in Table 1.

Mode	*What*	*When*
automatic	all current open tabs, bookmarks and annotations	immediately (or periodically in brief intervals)
snapshot		at a time specified by the user (via "commit" button), subsequent changes (new pages, closed pages, comments...) will remain private until the next "commit"
explicit	selected resources	personal search results are only accessible to the user (private) and not visible to team members until explicit sharing

Table 1: The three introduced modes for information sharing in relation to *what is shared* and *when is it shared*.

3.3 CoFind: A Browser Plugin for CIS studies

We developed our own Firefox[1] browser plugin called *CoFind* as a research tool for investigating group awareness (e. g., [9, 10]) in co-located CIS. The plugin has to be installed on every client device used in a study session. It connects to a dedicated data server which is part of our implementation and shipped with *CoFind*[2]. Besides notifying registered clients about states and updated content during a session, the server is responsible for logging various browser and plugin activities, such as open new tab, close tab, bookmark web page, scroll web page, click on hyperlink. *CoFind* implements the three sharing modes *automatic*, *snapshot* and *explicit*, from which the study leader can activate one at the beginning of a study session. The current implementation is intended for studies with groups of 3-4 people.

The graphical user interface of our plugin (Figure 1(A)) consists of two main components: a sidebar integrated at the left side of the browser and a landing page as a separate browser tab window. The sidebar comprises three spaces: a *group space* as a joint collection of bookmarked web pages, an *activity space* where users can share their currently opened web pages, and a *private space* allowing a user to access a list of currently opened web pages across different personal devices. The decision to provide these three spaces is based on related work of territoriality [17, 18, 21]. The *landing page* is accessible via detail buttons in the sidebar and shows more details of the content of sidebar "spaces", e. g., preview images of shared and bookmarked web pages. *CoFind* also allows users to create and share textual annotations of web pages (e. g., marked paragraphs or single words, user-added notes). Annotated web pages are automatically bookmarked.

4 LAB EXPERIMENT & PRELIMINARY STUDY

In a laboratory experiment, we tested the feasibility of our study tool, focusing on its general usability regarding sidebar sections and information representation, and applicability in a MDE with interactive display devices. In particular, we take a closer look into possible disturbing effects due to the plugin itself (e. g., interface updates caused by information sharing) and the chosen hardware setup (only touch enabled mobile and stationary interactive displays). With regard to the three modes of information sharing, we initially examined only the *automatic* mode in a preliminary study, as we assume obvious distraction.

Test Setup We recruited 9 participants (two females, aged between 24 and 30 years) and formed three groups (two mixed and one male group, members of each team knew each other). We chose a travel planning task: The group had to decide about a joint destination and find out ten tourist attractions or leisure activities nearby. After an introduction to web search with *CoFind*, each group had 30 minutes time to solve the task, using the provided display devices (three Microsoft Surface Go 2 tablets, two Microsoft

[1] www.mozilla.org/firefox
[2] GitHub repository: https://github.com/imldresden/cofind-plugin

Surface Hub 2S), each running a Firefox web browser with the *CoFind* plugin, and available web resources via Internet connection. The setup is shown in Figure 1(B). One of the larger displays was by default configured as digital whiteboard for making notes. All participants were familiar with touch or pen input. However, for the sake of simplicity and to exclude hardware-related usability issues we deactivated web page annotation which is typically easier with a physical keyboard. In addition to the data logged on the *CoFind* server, we produced audio and video recordings. We also recorded people's locations using a motion capture system that tracked augmented caps worn by each participant (Figure 1(B)). This was primarily done to verify the server's activity logs later on.

Initial Results Initial impressions confirm that *CoFind* is a reliable tool for the investigation of group activities in collaborative co-located web search in a MDE. In a follow-up interview, participants indicate that they did not feel restrained in their work, and felt well informed about the activities of their partners. No noticeable delays were observed regarding the cross-display information sharing on users' activities. The known issues of using the virtual keyboard with touch display were commented by some subjects. The logging shows the presence and alternation of typical collaborative search phases: individual search and cooperative discussion. Tablets were exclusively used for individual web search and the large shared display was used for discussions and cooperative search. Additionally, individual participants also used more than one device at a time (cross-device). After about half of the processing time the groups started to systematically select and delete bookmarked resources on the shared display device. However, the "activity space" in the sidebar was rarely used during individual search phases, but during joint discussions to quickly retrieve a visited link. The more active usage of shared information indicated the beginning of the discussion phase (about 80% of web pages were opened via shared bookmarks).

5 DISCUSSION AND OUTLOOK

As mentioned above, deploying our developed *CoFind* plugin in a first laboratory experiment allowed us to observe several aspects relevant to group awareness. It was noticeable that teams went through typical CIS working phases (e. g., individual work on personal displays, discussions at shared display). Our experiment also showed, that team members intensively communicated verbally in cooperative working phases. This avoided unnecessary duplication of work, but as a result the "activity space" was not exploited in its full potential during the *automatic* information sharing. We think that this is mainly due to the short duration of the sessions, assuming that longer periods of individual work could benefit from this feature. In this respect it would be interesting to examine and compare the other proposed modes regarding level of distraction vs. support of group awareness.

A final collaborative search tool could, of course, implement many more useful features, which was, however, not criticized by our users. For the user-defined time of information sharing (*snapshot, explicit*), additional features may be required, such as notifications to indicate changes (who and what) to group members. *CoFind* as an additional and auxiliary plugin allows for information sharing in MDE for co-located CIS, without distracting users or obstructing individual or cooperative work. Thus, it provides a research tool that offers lightweight assistance to users, but also full logging and tracking functionalities to researchers for the analysis and evaluation of CIS scenarios.

As part of future research opportunities, we propose to also investigate different visual representations of shared information. This might support both the group itself and researchers for assessing group performance. For example, our *CoFind* could be improved by more advanced and efficient adaptive visualizations of group activities and (interim) results. Again, the actual mode of information sharing plays an important role. While in *automatic* mode all data is basically shown in real time, it appears to be particularly important for both *snapshot* and *explicit* mode to focus on highlighting changes between events.

In addition, we think it would also be worth to further explore characteristics of different working phases in such CIS sessions. That might allow to develop tools that actively support groups while transitioning between different work phases.

Furthermore, from our experience with MDE and various devices, we think another powerful factor of influence to be investigated is the actual set of available devices and their roles. We believe that specific device properties, such as the *form factor* ranging from small smartphones to large wall-sized and shared displays or the *type of input modality* (e. g., keyboard, touch, pen), have a strong impact on the way people proceed. In order to design and develop effective collaborative workplaces, this should be studied in more detail. Also a hybrid approach of information sharing would be imaginable with *explicit* mode for personal devices and *automatic* mode for shared devices.

We hope that this on-going investigation as well as our *CoFind* prototype will inform and inspire future work on co-located collaborative information seeking.

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