

A Comparative Study of Collaborative and Individual Web Search for a Social Planning Task

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Abstract

In this paper we describe the results of a study which compares explicit synchronous collaborative web search with searching the web individually when users are utilizing the web for the purpose of social planning tasks, in specific travel planning. We explore both co-located and distributed collaborative search within groups of two and three participants. The distributed collaborative search is supported by SearchTogether. The results show that distributed collaborative search in general outperforms both co-located and individual search. Surprisingly, the increase of the group size negatively influences the search results, though it positively affects the user confidence in the search results. We conclude that the negative effect arises due to an increased communication effort and suggest future work in HCI to better support collaboration in large groups.

Keywords: collaborative search, user study, web search

1 Introduction

Web search was for a long time seen as a single user activity. Due to this, existing search engines were primarily developed for individual usage. However, recent studies show that users regularly collaborate when searching the web [Evans and Chi, 2008; Morris, 2008]. As the field of collaborative search is relatively new, there is some uncertainty in definitions. In this work, two concepts shall be distinguished: social and collaborative search.

Definition 1 *Social search describes search acts that make use of social interactions with others. These interactions may be explicit or implicit, co-located or remote, synchronous or asynchronous [Evans and Chi, 2008].*

In social search the users interact before, during and/or after the search. This definition includes individual searches of a single user, who interacts with others to improve his understanding of the search problem before searching or to share the search results afterwards. However, only a single user is actively searching. Those cases are excluded from our definition of collaborative search:

Definition 2 *Collaborative search is a special case of a social search, in which all participants have the same information need and actively conduct a specific search together in order to achieve a common searching goal.*

In our work, we concentrate on collaborative search and perform a user study to compare different variants of collaborative search with individual search on a social planning task like travel planning. In particular, we addressed the following research questions:

- Does collaborative search lead to better results than individual search for a social planning task?
- Does the group size influence the search results?
- Does it influence the group work, if participants share a single computer or if they use a computer each?
- Does the user information gain depend on whether users are searching individually or collaboratively?
- Do users prefer searching individually or within a group?
- Does the group size influence a user's appraisal of the search success?

The remainder of the paper is structured as follows. In Section 2, we outline related work and introduce our research questions. Section 3 describes the design of the study and Section 4 its main findings. Finally, Section 5 concludes the paper and discusses possible future work.

2 Related Work

Collaborative search is a recent research topic. In [Golovchinsky *et al.*, 2008], different dimensions of collaboration are discussed such as intent (explicit and implicit), depth of mediation, concurrency and location. Depth of mediation distinguishes how deep the underlying IR-system influences the search: only via the user interface or even using algorithms to affect the search results based upon each user's search activity. A recommendation system such as *I-Spy* [Smyth *et al.*, 2003] is a good example of a deep algorithmic mediation while *Search Together* system [Morris and Horvitz, 2007] is an example of UI-level mediation. The concurrency dimension distinguishes how synchronized the search process is: synchronous vs. asynchronous. In asynchronous case the search members do not work at the same time, while in synchronous case they do. The main difference here is that the synchronous search makes it possible that each team member's actions can influence the activity of other team members. In asynchronous case those who search later benefit from collaboration, but the earlier ones search like individual users. Depending on the location the collaborative search may be co-located or distributed. In our work we restrict ourselves to explicit synchronous collaboration supported by only an user interface. We explore both co-located and distributed case of collaboration.

A lot of work was already done in the field of implicit collaboration, where the retrieval system supports users by taking historical search data of other users into consideration, e.g. [Smyth *et al.*, 2004; Linden *et al.*, 2003; Smyth *et al.*, 2009]. Explicit collaboration means that users share the same information need and conduct a search activity together (usually in a small group) to achieve this goal. The most prominent system which supports explicit collaboration is *Search Together* [Morris and Horvitz, 2007].

Several user studies on collaborative search have been done in the past. These studies have shown that people do collaborate when performing searches [Twidale *et al.*, 1997; Morris, 2008; Evans and Chi, 2008]. The studies have explored some aspects of collaborative search such as collaborative search strategies and tasks [Morris, 2008] and children collaboration behavior within same-sex groups [Martin, 1998; Leong and Hawamdeh, 1999; Large *et al.*, 2002]. Concerning search effectiveness, past research could not show an advantage of collaboration. In one experiment [Joho *et al.*, 2008], collaborative search on a recall-oriented task within a document collection was not more effective than the individual search.

Nevertheless, there is an increasing trend in HCI to examine how to better support collaboration among users of information retrieval systems [Hearst, 2009]. In [Amerishi and Morris, 2008], the tool *CoSearch* was suggested, which enables multiple users to perform their search activity on one computer with several mice or mobile devices. The study showed that the participants preferred such co-located collaborative search to searching individually on their own computers. Another tool that supports co-located collaborative video retrieval was implemented on a table with a touch-panel screen. The evaluation of the system led to the conclusion that a system designed to make users aware of each other activity is not only preferred by users, but is also more effective [Smeaton *et al.*, 2007]. The *SearchTogether* system¹ was developed to support remote collaborative search, allowing users to share search results across computers. The quality of the system was evaluated for on its support for synchronous collaborative search for groups of size two [Morris and Horvitz, 2007]. As key success components, the study identified awareness, support for a flexible division of labor, and the opportunity to automatically summarize the search.

With our study, we contribute to the analysis of the effectiveness of collaborative search. We did not use a recall-oriented task as in [Joho *et al.*, 2008] but rather a social planning task (like travel planning, general shopping tasks, literature search), because previous studies discovered it to be a typical multi-user Web search activity [Morris, 2008]. In contrast to previous studies we did not restrict ourselves to a fixed document collection but allowed participants to search the Web in order to observe user behavior in a more natural setting. In particular, we compared co-located and distributed collaborative search. Furthermore, we investigated the influence of the group size, which was not done in previous studies.

3 Study Design

Our study was performed as a lab experiment combined with a questionnaire. Before the lab experiment, the partic-

ipants completed a questionnaire about their demographic information, their web search experience and their previous knowledge about the search task. In the lab experiment, the participants were asked to solve a social planning task using the web, in specific to plan a travel. Afterwards, a second questionnaire collected their results on the task. Additionally, their search activity was captured by a proxy which stored the visited websites.

The central element of the experiment is the search task. If it is too simple, collaboration is not needed for solving it [Morris and Horvitz, 2007; Shah, 2008]. If it is too difficult, it would be out of the scope of a lab experiment. Therefore we selected a travel planning task, which is a typical collaborative task [Morris, 2008] with medium complexity. Specifically, we asked our participants to find the cheapest travel plan between two cities while traveling within a day. We chose those cities in a way that direct traveling was expensive and a good solution required several intermediate steps, which were not known in advance. We allowed for a maximum search time of 45 minutes, which was often used entirely by the participants. We used 3 different group configurations to analyze variants of collaboration:

ind configuration. One subgroup of participants searched individually.

co configuration. Another subgroup searched in groups, sharing a single computer. This configuration implements explicit, synchronous, co-located collaborative search [Golovchinsky *et al.*, 2008].

dist configuration. The rest of the participants searched in groups, having a personal computer each. This configuration implements explicit, synchronous, distributed collaborative search [Golovchinsky *et al.*, 2008]. The distributed search was supported by *SearchTogether*. *SearchTogether* is a free Internet Explorer plug-in. It allows each group member to see a group query history, to chat about the search, to watch and contribute to the session summary: a list of all web pages that have been annotated (rated or commented on) by any group member²[Morris and Horvitz, 2007]. That means these participants were aware of search queries of other group members and the web pages they had marked as relevant. They also could communicate with each other in a chat.

The search groups were formed such that group members knew each other well. This was done to avoid negative effects due to unfamiliarity between group members, which could hinder efficient collaboration. For both group configurations, groups were formed with 2 or 3 participants.

60 participants assisted in our study: 31 men and 29 women. The participants were between 20 and 28 years old. Most of them were students studying computer science or biosystems technology and have frequently used the Internet for several years. They extensively use the web for work-related research, for reading news, for entertainment, and for shopping. For searching, they mostly use *Google*. Hence, the participants were quite homogeneous. This is also true for their personal evaluation of their previous search success, which was mainly seen as often successful. The participants of different search configurations had about the same distribution of prior knowledge about

¹<http://research.microsoft.com/en-us/um/redmond/projects/searchtogether/>

²We do not mention other features of the used software (like split searching and peek-and-follow browsing) because they did not work or were not used by users at all.

the search task. Therefore, the differences in the results of their search are due primarily to the search configuration.

4 Main Results

In this section we present the main results of our user study. We explored different search configurations comparing them via different criteria: objective like costs of the travel trip, the number of visited web sites and queries and subjective like user feeling, results assessment and information gain.

4.1 Objective criteria: trip cost

To measure the success of the search, we compared the costs of the trip of the different configurations. As several groups shared one lab, we had two different search tasks such that neighboring computers had different tasks: from *Magdeburg* (Germany) to *Galway* (Ireland) and from *Magdeburg* (Germany) to *Dundee* (Scotland). To combine the results for both tasks, we transformed both normal distributed result sets to a standard normal distribution and then merged the two. The final results are given in Fig. 1 (smaller is better). In addition to our actual groups, we built *virtual* groups (*ind2*, *ind3*) from the individually searching participants and took the best price as group result. Through this, we studied synergy effects by comparing explicit and implicit collaboration.

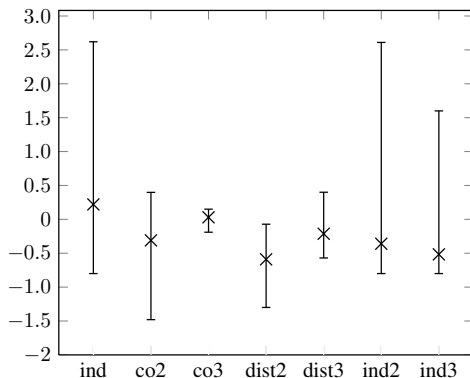


Figure 1: Normalized price results of different configurations (mean and price interval, smaller is better).

The results indicate that collaboration leads to better results. This is mainly because relatively bad results are avoided in a group, if at least a single person can find a good result. True synergy effects are hard to measure. The best indication for synergy effects is given through comparing the *dist2/3* with the *ind2/3* configuration. For groups of two, we found that explicit collaboration improved the search result, although the difference is small and unfortunately not statistically significant. Further experiments with larger user sample are needed to make an accurate conclusion. The small difference can also indicate that the searching task was not difficult enough to benefit from collaboration [Morris and Horvitz, 2007; Shah, 2008]. In general, distributed search provides better results than co-located and individual search. This effect probably arises from the larger active search time in the distributed groups because group members can search in parallel. Nevertheless, co-located search groups still get better results than individual searchers although the active search time is the same or even less due to communication

between group members. This indicates further benefits through collaboration.

For an increasing group size, we would expect better results as shown for the implicit groups *ind2/3*. Surprisingly, this was not true for the explicit groups, for co-location as well as distribution. We conclude that the cause for this lies in bigger communication efforts of larger groups: it gets more difficult to keep track of the results of the other groups members, which, however, is wanted in (true) collaboration. An indirect argument for this conclusion can be gained by comparing the participants' questionnaire answers about the role distribution within groups. After the search experiment the participants indicated whether there was a leader(s) within a group or every member had an equal contribution to the search. As not all answers were consistent within groups, we used the following heuristic: if even one group member indicated a leader then there was a hierarchy in a role distribution.

The participants used the following role distributions: no coordination, leader by-turn, with leadership, equal contribution (Fig. 2). The communication effort in groups of three forced one of the members to take leadership, coordinating the search activity among the group members ("with leadership" role distribution). Fig. 2 shows that for both explicit group configurations a higher fraction of groups indicated a leader for groups of three than for groups of two. This was especially true for distributed search as all groups of three had a leader.

"No coordination" role distribution means that the participants searched by themselves without coordinating the search activity and took the best result in the end. Several co-located groups used "leader by-turn" strategy, where group members actively searched by turn. In some groups the members made an equal contribution to the search activity ("equal contribution" role distribution).

4.2 Log file analyses

We also analyzed the log of visited web sites. Search groups visited more different websites than individual searchers (Fig. 3, left). Those difference were found to be statistically relevant using ANOVA test. The difference in the amount of visited websites between *ind* and *co* configuration ($p < 0.05$), *ind* and *dist* configuration ($p < 0.01$) was found significant with the help of the LSD test (ANOVA Post-Hoc-Test)³. Especially the difference between individual and co-located search demonstrates the advantages of collaboration because the one available computer was used more effectively through exchanging experience and knowledge. The search groups also formulated more different queries to search engines than individual searchers (Fig. 3, right). This is especially true for the distributed search, where participants created a lot more different queries.

Here the explicit collaboration through SearchTogether brings additional benefit as it results in a lot more different queries than in our virtual groups of implicit collaboration. But the number of queries does not translate to better search results of distributed groups *dist3*, since the quality of search results of cause relate also to the quality of the queries and not only to their number.

³For each comparison mentioned in the paper we did statistical tests. But only these differences were found significant.

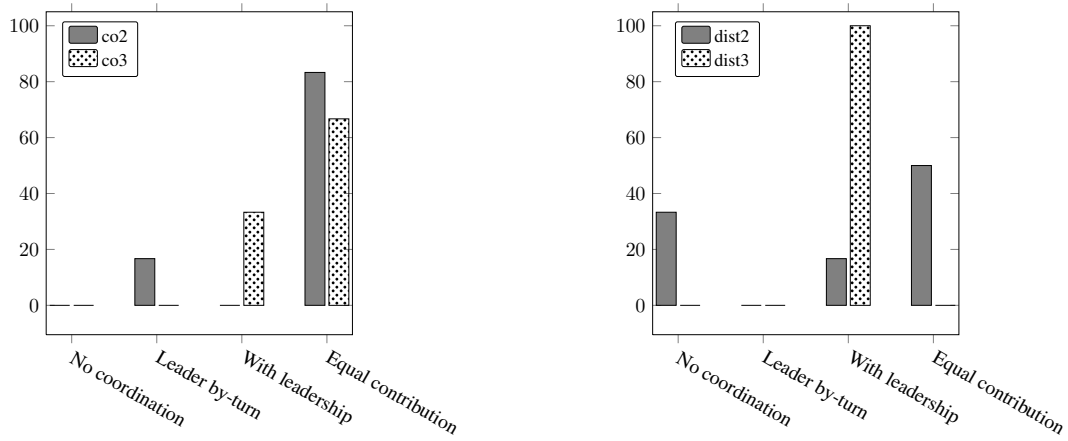


Figure 2: Role distribution of different group configurations.

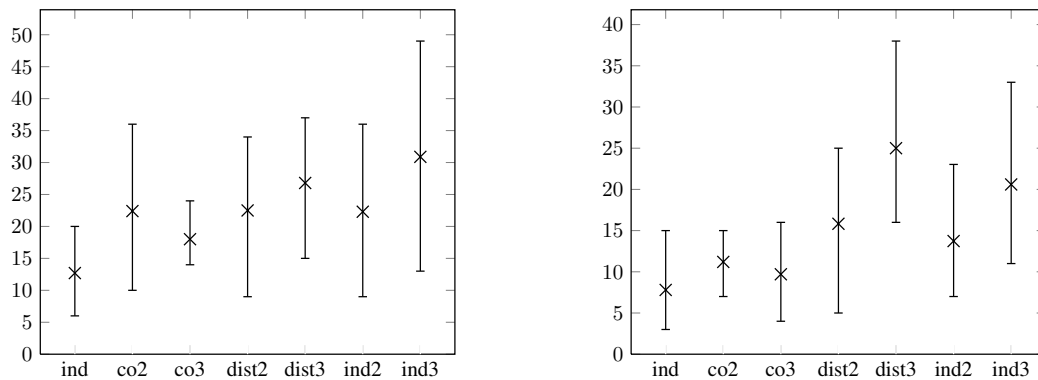


Figure 3: The number of different websites visited per group (left). The number of different search queries per group (right). Both figures show mean and interval.

4.3 Subjective criteria: user feeling and satisfaction

In Sections 4.1 and 4.2 we used the price result, number of queries and visited websites as objective measures to compare different search configurations. It is also of interest to evaluate user's appraisal of the search success before the search and user satisfaction after the search. For this purpose we analyzed how many users already did collaborative search and whether they think the collaboration improves the search results before the search experiment. We evaluated the user's appraisal of the search success after the search was conducted and compared both results. We obtained this data from the questionnaire filled before and after the experiment.

36,7 % had already an experience in collaborative search. This is consistent with previous study [Morris, 2008], where 30,4 % instant-messaged other people to coordinate Web search. 33,3 % indicated other users helped them with search advices. Thus 70 % had already an experience in social search (see Table 1). This results are consistent with previous study [Evans and Chi, 2008], where 2/3 users communicated with others during the web search. Little more than a half of participants judge the collaborative search to be more successful (see Table 2).

Participants who already had some experience with social search, were more convinced that the results of the collaborative search are better than by individual search (Fig. 4; All participants with no experience that feel no need in collaboration estimate individual search to be more

successful.).

In order to evaluate users' own *subjective* opinion about the search results participants were asked to fill in the questionnaire after the search experiment and estimate their search results (Table 3). 1/3 of individual searchers thought to have found the best travel route. This was the case by 52 % of the participants that used *co*-configuration and 33 % that used *dist*-configuration. That means the participants who searched in a group using one computer were more confident of the search results. When comparing the user confidence in relation to the group size, the participants who searched within groups of size *three* were stronger convinced to have found the best travel plan as the participants within groups of size *two*. This difference is particularly strong by *dist*-configuration: 8 vs. 58 Percent.

4.4 Subjective criteria: knowledge gain

Inspired by the paper [Spink, 2002] we also compared the difference in an *information seeking stage* of participants in dependence of the search configuration. The authors in [Spink, 2002] asked the participants to indicate their current information seeking stage before and after their web search using a questionnaire. The difference of these two should measure the subjective knowledge gain of the participants about the search topic. We adopted this methodology but slightly modifying the stages to fit our task. We used five stages as described below:

1. I know the cheapest travel plan.
2. I know some (one or more) possible travel plans.

Experience	%
in social search	70,0
in collaborative search	36,7
no experience	30,0

Table 1: Participants experience in social and collaborative web search.

Search results are better	%
if searching individually	43,3
if searching collaboratively	53,3
no answer	3,3

Table 2: User estimate of collaborative search.

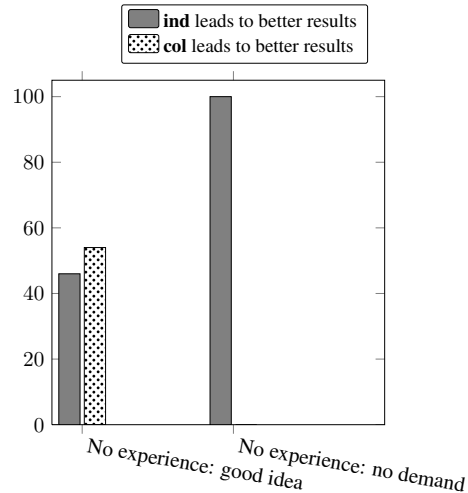
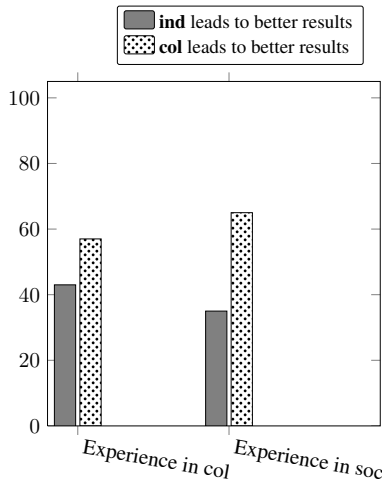


Figure 4: User estimate of collaborative (*col*) and individual (*ind*) search in correlation to user experience: which search type leads to better results (in percent). Participants with experience in social search are left, with no experience are right. Experience in *col*: participants with experience in collaborative search. Experience in *soc*: participants with experience in social search (with only passiv help of others.)

3. I do not know any travel plan, but I know web resources which can help me to find a travel plan.
4. I do not know any travel plan, but I have a *rough idea* where I can find information I need.
5. I do not know how to create such a travel plan.

We assigned a 5-points scale to the answers: from 1 (stage 5) till 5 (stage 1)⁴. The average knowledge gain by different search configurations is shown in Fig. 5 and is approximate equal regarding the different search configurations. This fact was also confirmed using ANOVA test. We also compared the average knowledge in different search configurations before the search experiment (Fig. 5, left). It was needed to ascertain that the participants of all configurations had the same prerequisites for the search. On average the participants of all configurations were in the same (fourth) information seeking stage. ANOVA test indicated no significant differences as well. Thus the subjective knowledge gain of the participants about the search topic does not seem to depend on the search configuration.

5 Conclusion

In this paper, we presented results from a user study of 60 people comparing explicit synchronous collaborative web search with individual (and implicit collaborative) search while utilizing the Web for social planning tasks, in specific travelling. We explored different variants of collabo-

ration, distributed as well as co-located, and varied group size between two and three. We compared these variants using different criteria: objective like costs of the travel trip, the number of visited web sites and queries as well as subjective like user appraisal of the search success, results assessment and information gain.

We found some indication for benefits in search through collaboration, for example by creating more queries. The search results also show signs of improvement in case of collaborative search but the difference was unfortunately not of great significance. We argue that a social planning task even if it is more complicated as a recall-oriented task in [Joho *et al.*, 2008] might still be not complicated enough to benefit from collaboration. But within a labor setting it is very complicated to design an experiment with a more complex searching task. A more complex task requires a longer time to be solved. For the future work, we want to conduct a longitudinal study to overcome this problem. We also intend to recruit experts in different domains to participate in the future study. With their different experience they may really benefit from collaboration by making it possible to combine the knowledge expertise of each.

However, the results also show that group work has some problems, due to an increased communication effort. In larger groups it is more difficult to keep track of the results of the other groups members, which, however, is wanted in true collaboration. We also found that the user confidence in the outcome of a search grows with the group size. The participants who searched within groups of size *three* were stronger convinced about the quality of the search results as the participants within groups of size *two*. However, it

⁴We made an assumption that the distances between the options are the same. Therefore, we can consider the data as interval-scaled (metric) and can calculate difference and average values.

Configuration	Answers, %		
	Probably the best	There's definitely a better one	I do not know
<i>ind</i>	33	67	0
<i>co2</i>	42	50	8
<i>co3</i>	67	33	0
<i>dist2</i>	8	84	8
<i>dist3</i>	58	17	25
<i>co (2 & 3)</i>	52	43	5
<i>dist (2 & 3)</i>	33	50	17

Table 3: User's appraisal to have found the best travel route.

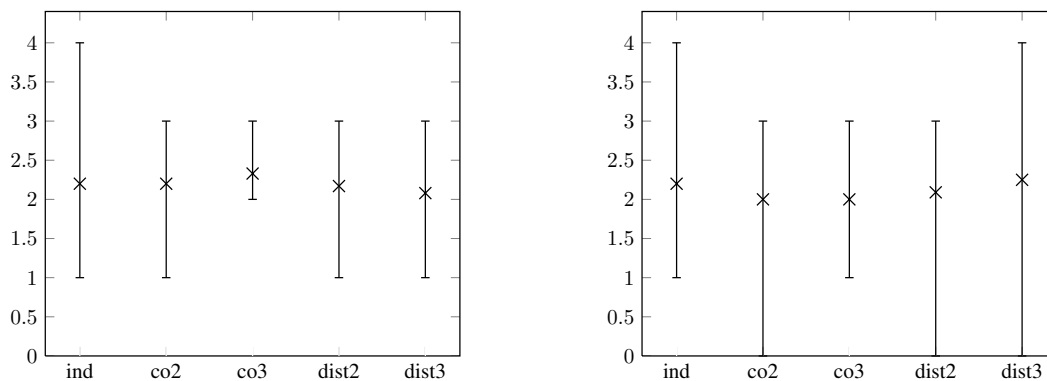


Figure 5: Left diagram shows the average knowledge of participant in different configurations before the experiment. Right diagram shows the average knowledge **gain** of participant in different configurations (for both figures mean and interval is shown, bigger is better).

might be interesting to study if the effect persists or gets even stronger in much larger groups. As for different search configurations, the participants of collaborative configuration are equal or more (in case of co-located search) confident in the results as the participants with individual search configuration.

In the future, it must be examined how communication can be efficiently supported through collaborative search systems, for example by specifically supporting leadership of a certain group member. We definitely see potential for collaborative search, if we succeed in developing enhanced interfaces and interaction techniques to support collaboration.

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