Search Assistant: Effect of Chatbot on User's Collaborative Search Behavior

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ABSTRACT

Collaborative search is "the retrieval and sensemaking of information by multiple users with the same information need" [14]. The experience of collaborative search can be improved by employing a chatbot which is "a program designed to counterfeit a smart communication" [5]. Chatbot makes it easier for the users to be aware of each other's activities and to share, communicate and reach consensus during collaborative search and makes it more enjoyable [3]. However, the prior research has been limited by using a single-user web search engine and a dedicated messaging platform. It is unknown whether the observed benefits are maintained in a collaborative search system where several collaborative tools exist, such as shared query history, bookmark, and built-in messaging capability. Hence, here we aim to explore how chatbot affects users' behavior on a collaborative search system and users' perceptions of the chatbot. We implemented ChatX, a chatbot agent that monitors the group chat and guides users through the search tasks. To evaluate it, we conducted a user study with 8 users in the domain of restaurant recommendations and local attraction searching. We found that ChatX does not significantly reduce users' search effort, but it improves the overall collaborative search experience and gives the user a highly favorable impression.

1 INTRODUCTION

Web search plays a vital role in people's lives, and people increasingly collaborate to satisfy their information needs. According to a study conducted in 2011, 92% of adults in the United States have used search engines [13]. Even though web search is considered to be a solitary activity and most of the search engines are designed to support a single user [11], people tend to collaborate more and more on search tasks. In 2006 and 2012, the two surveys conducted by Morris indicate that people's engagement of collaboration on search tasks had increased from 53.4% to 65.3% [9, 10]. Therefore, it is crucial to understand the factors of collaborative search and how they affect users' search behaviors.

Collaborative search is an activity in which multiple parties participate and work towards a mutually beneficial common goal. It usually involves information lookup, sharing, synthesis, and decision making [16]. Most of the real-world collaborative search is done via a dedicated messaging platform as the communication channel and a single user search engine [3]. Single user search engine, such as Google, does not have built-in communication channel or features that raise awareness of collaborators' activities. However, as collaborative search being actively researched, many dedicated collaborative search systems have been developed, such as SearchTogether [10], Coagmento [6], CoSearch [2], CoSense [12] and SearchX [14]. These systems provide features like shared query history, shared bookmarks, shared notepad, and chat, besides searching for information.

Communication has a significant impact on users' collaborative search behavior. [16] defines the three predominant components of collaboration as control, communication, and awareness, and among the three components, communication is the most crucial one. Typically, people communicate with others by exchanging messages via chat during a collaborative search session. Morris' study shows that more than 1/3 of the users chat while collaborating on web search. Furthermore, [17] find that 28.9% and 43.5% of the query terms are provided by chat content in academic search tasks and leisure search tasks, respectively.

On messaging platforms like Slack, Telegram, or Facebook messenger, chatbots have been used to help users with single-user tasks. For example, a chatbot can find a song or retrieve information for users. In [3], they explored the effect of employing a chatbot to aid users in the collaborative search session with an ad hoc combination of single-user search engine and messaging platform. They found that chatbot improves collaborative search experience and reduces the need for the participants to search independently.

However, no research has been done on whether chatbot has the same effect on users' collaborative search experience with a dedicated collaborative search system. Investigating this topic provides insights into possible ways to improve users' collaborative search experience and how users interact with the chatbot. Therefore, in this paper, we propose a design and implementation of a chatbot and answer the question: **What is the effect of the chatbot on participants' collaborative search experience?** We address this question from two perspectives: First, the users' perception of the collaborative search experience. How does it change with or without the chatbot. Secondly, the objective measurement of participants' searching efficiency. We measure metrics such as the completion time of search tasks, the number of queries, and messages exchanged.

To tackle the research question, we conducted a user study in which participants carried on search tasks in groups with or without help from the chatbot. By analyzing the metrics and results of the questionnaire, we found that chatbot has no significant effect on reducing users' collaborative search effort. However, it significantly improves users' overall collaborative search experience.

2 BACKGROUND

There are three fundamental concepts that this research built upon collaborative search, collaborative search system, and chatbot. In this section, we introduce the prior works and findings to provide context for readers unfamiliar with these areas.

2.1 Collaborative Search

Morris [11] defined collaborative search as "a group of users working together on a shared information-seeking goal." So we look at collaborative search from two viewpoints: information seeking and collaboration.

According to [11], information seeking is not simply searching and retrieving information but also includes browsing, sharing, assessing, and synthesizing information. For example, when a user searches for a restaurant, she is not just looking for any restaurant, but a restaurant that satisfies her preference. During the process, she will browse multiple restaurants, view comments, compare different restaurants on various aspects, and decide. This process of task completing and problem-solving via looking for information is referred to as information seeking [16]. Information-seeking tasks like the one mentioned above can sometimes be challenging and complex or involve other parties' benefit, and this is where the collaboration comes into play.

In [16], *collaboration* is defined as "an activity of multiple parties coming together to work toward a mutually beneficial common goal." It models collaboration with a five-layer model which has *communication* at its core, and each layer supports its outer layer. For example, the contribution layer is supported by communication since individuals rely on sending or exchanging information to help each other achieve personal goals during collaboration search sessions. Moreover, with collaboration as the outmost layer, it indicates communication is essential for meaningful collaboration.

2.2 Collaborative Search System

Single-user search engines such as Google and Baidu are designed to satisfy a single user's information need by returning a list of results from the user's query, which usually consists of key words [11]. On the other hand, the purpose of a collaborative search system is to facilitate collaboration during the process of information seeking. According to the collaboration model in section 2.1, a collaborative search system should provide an effective way of communication, allow individual contribution, and coordinate individuals' requests and responses [16].

SearchX is the collaborative search system used in this research as it is open-sourced and does not require installing of any browser plugin or app. In [14], a study has been done on the main collaborative features of SearchX, including chat, shared bookmarks, and query history sharing. Results show that more than 60% of users consider shared bookmarks and query history useful features, while only 24% of users consider chat useful.

2.3 Chatbot

A *chatbot* can be defined as an "online human-computer dialog system with natural language" [7]. For inexperienced users who are not experts in computer applications, the three expected major functions of a chatbot are: dialogical agent, rational agent, and embodied agent. [4]. This means that the chatbot must understand the users, respond to users' requests, and provide a feeling of presence. For expert users, the embodied agent can be optional [4].

Natural Language Understanding ability(NLU) is essential for a chatbot to understand and respond to user's requests. The NLU module of the chatbot extracts structural information such as intent and entities from the user's text message using machine learning and Natural Language Processing(NLP) techniques [1]. Hence, It is not easy to build a chatbot from scratch, as it requires comprehensive knowledge of NLP and extensive data set for model training. In this research, we choose to use a framework with pre-trained models to build our chatbot. Pre-trained models have learned universal language representations from a large corpus and thus provides better results when trained with fewer data comparing to training a new model [15].

3 METHODOLOGY

A user study was conducted to tackle the research question. The setup of the study was based on [3] where the users carry search tasks with three different chatbot conditions: with a bot that only ask questions and does not learn from the conversation, with a bot that learns from the conversation but does not ask questions, and without a bot. Each group consists of two participants and carries out three search tasks in a session with distinct bot conditions. The setup can easily be adapted to our research. In this section, we introduce how is the user study carried out and what is the different between the setups in [3] and our research.

3.1 Participants

Eight participants were recruited from the *convenient group*(friends or families that we can conveniently access) due to the limitation of resources. The participants are composed of three females participants and five male participants. They all have a higher education background with a good command of English and agreed only to use SearchX during the study. The participants are divided into four groups with two participants per group, and they were asked to conduct two search tasks and answer the survey questions after each search task is completed.

3.2 Study Protocol

We employed a similar study protocol as in [3], the whole process of the user study is illustrated in Figure 1. Before the study begins, participants were first informed about the study protocol. Instructions on how to use features of SearchX are given to the participants. They were also told that they could interact with the chatbot proactively or the chatbot will intervene when infers required information from the chat, and it may ask questions to gather information. Moreover, the chatbot will search on behalf of them if it has collected all required information. Then, the participants were given a practice search task, "Searching for a hotel to stay at during their vacation together" to familiarize themselves with the system. In the practice task, the participants are asked to write down their preferences, whereas, in the formal tasks, they are given pre-determined preferences

When the experiment began, each group of participants was assigned two search tasks described in the following subsection. The order of the tasks was randomly chosen to eliminate potential order effects. For each task, half of the groups were randomly picked to conduct the task with the chatbot, while the other half completed the task without the chatbot. The participants have access to all other SearchX features during the entire study. Participants were

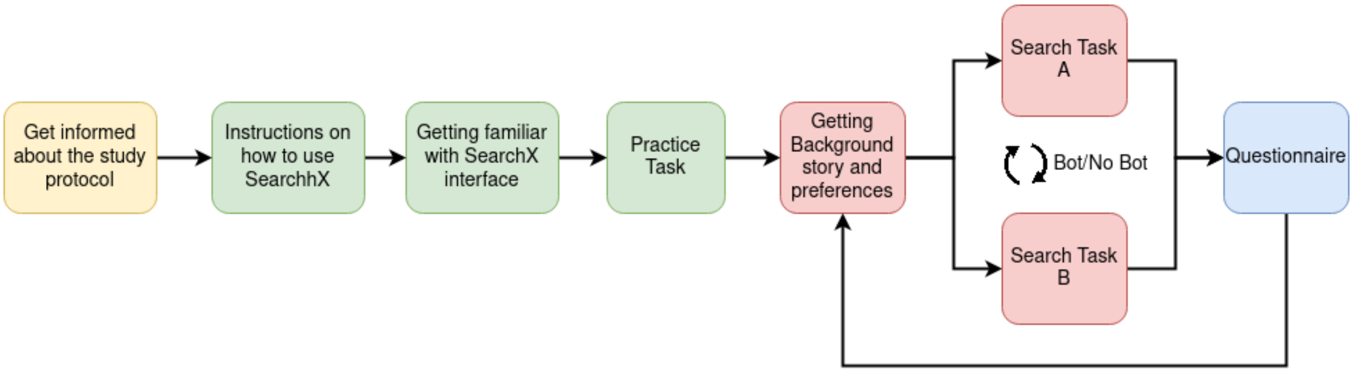


Figure 1: User study process for each group of participants

only allowed to use SearchX for both information retrieval and communication.

Participants' screen activities were captured, and their query history and chat content were logged. Upon accomplishment of each search task, they were asked to fill in a questionnaire.

3.3 Search Tasks

Besides the practice search task, each group of participants conducted two search tasks: (1) finding a restaurant, (2) finding a local tourist attraction. These search tasks are the same ones as in [3]. We use the same tasks because these tasks are all about travel planning which is the most common collaborative search task [11]. It is easier for the participants to collaborate on it. Also, using the same tasks makes the result of the research more comparable.

Each search task comes with a background story and preferences for each of the group members. In the background story, each participant is given a gender-neutral name such as Zhou and Li. A scenario that requires them to collaborate on a search task is created to provide conversation context for the participants. The preferences are meant to emulate how collaborative search happens in the real world, where people tend to have their own preferred choice. An example background story and preferences look like the following:

Background story: *Zhou and Li have been friends since they were 5, they used to hang out all the time. However, after high school, Zhou went to the Netherlands to study at TU Delft for his bachelor's degree, while Li went straight to work. They have not seen each other for more than five years. Li will visit the Netherlands for a business trip and has one day he can spend with Zhou. So the task is to find local attractions to visit during Li's stay in the Netherlands.*

Location constraint: *Li has only one day to spare, and Zhou doesn't have the budget to travel far. So they decided to find somewhere interesting in Delft.*

Attraction type constraint: *Zhou is a computer scientist who stays in front a screen most time of the day. After realizing that his health condition is deteriorating, he decided to change his lifestyle and embrace nature more. Li does not care about which place they will visit as long as he can spend some time with Zhou. So they decided to find some natural landscape.*

The constraints for finding a restaurant are cuisine type and location.

3.4 Post-task Questionnaire

Each participant fills in the post-task questionnaire after completion of every search task. It consists of three parts: collaborative search experience, perception of the chatbot, and general open-end questions. The first part consists of statements about participants' awareness, effort, and enjoyment of their collaborative search activities. Participants rate each statement from 0 to 10, where 0 indicates disagree and 10 indicates strongly agree. Part one is always given to the participants, whereas the second and third parts are only given to participants when the task is conducted with the chatbot. The second part has an emphasis on participants' impressions of the chatbot. It asks whether the chatbot is distracting, annoying, helpful, or helps save time, provide useful information, discover new information, and inspire the user. The last part consists of two questions that ask the participants how the chatbot helps them or why it does not help them during the search task.

4 EXPERIMENTAL SETUP AND RESULTS

The experiment was conducted online. We hosted SearchX and ChatX on AliCloud, such that they could be accessed by all participants with a browser that supports ES6 features. In this section, SeachX and ChatX are described, followed by how the data was analyzed.

4.1 SearchX: the Collaborative Search System

SearchX[1] is an open-source scalable collaborative search system. Figure 2 illustrates the interface of SearchX with the following features:

- **Search Bar**: SerachX provides search service with configurable search providers which can be chosen from Bing, Elasticsearch and indri.
- **Recent queries**: recent query history of the collaborative search session, which is shared within the group.
- **Saved documents**: user saved documents that all group members can see.

[1] https://searchx.info/

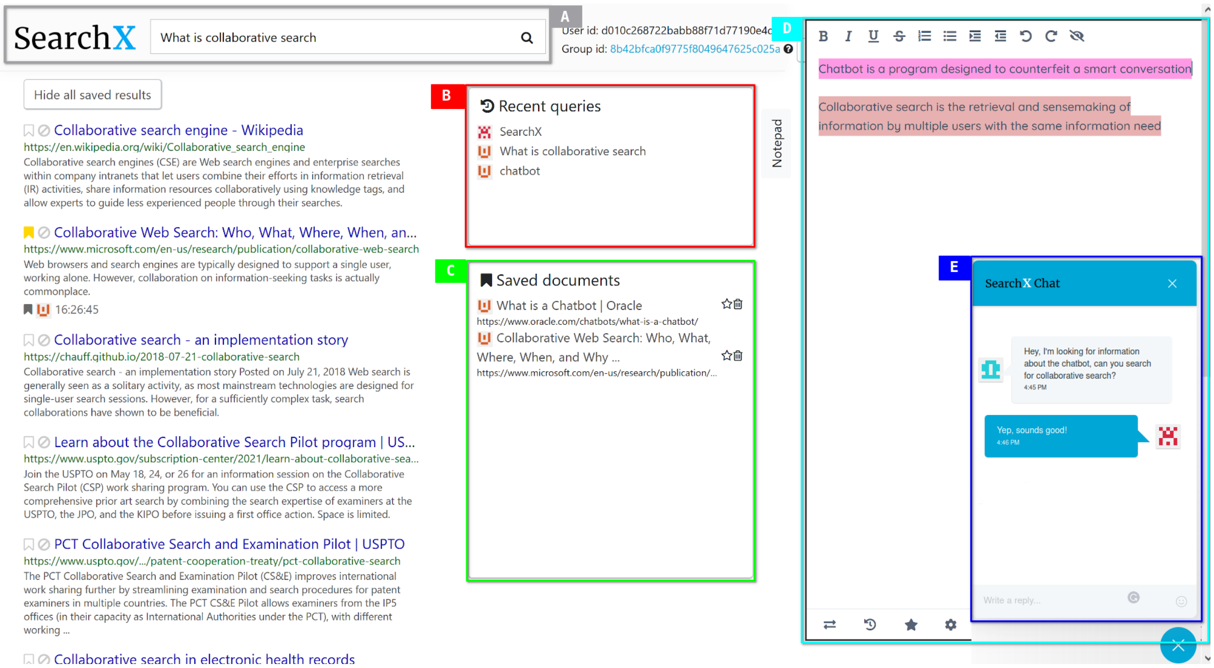


Figure 2: SearchX Interface. [A]Search Bar,[B]Recent Queries,[C]Saved documents,[D] Shared Notepad,[E] Chat tool

- **Shared notepad**: a notepad of which the content can be viewed and edited by all group members.
- **chat tool**: a simple chat widget that allows users to exchange text(emoji) messages.

With SearchX, when the user starts a new session, a random session ID is assigned, and it also serves as the group ID, which identifies the collaborative search group. Other users can join the group by setting the "groupid" argument in the URL. Leveraging the features mentioned above, users are more aware of group members' activities and can communicate within the group synchronously with the chat tool or asynchronously with the notepad.

The front-end of SearchX is a web application written in JavaScript with React framework. It features shared components, such as bookmarks, queries, and chat widget. These components share the same state among users in the same group. The chat widget is implemented in an external module called SearchX-chat and included as a dependency. The back-end is a Node.js server that contains search task components, retrieval components, logging components, and document renderer [14]. The front-end communicates with the back-end via the RESTful API or Socket.io.

4.2 ChatX: Extension of SearchX

As the prerequisite of the research, we implemented ChatX, a conversational search assistant, which satisfies the following minimum working requirements:

- It must be able to monitor the group conversation.
- It must be able to *understand* (infer user's intention, extract entities from messages, and be aware of the context) the conversation
- It must be able to intervene in the conversation
- It must be able to react to user's direct requests
- It must be able to retrieve the requested information
- It must be able to present the retrieved information
- It must be able to handle the two domains used in this research: restaurant finding and local attraction finding
- It must be compatible with SearchX

Figure 3 illustrates the high-level structure of ChatX. Since SearchX only support textual(emoji) message by default, we first extended the SearchX-chat module to add support for rendering bot specific messages. It was done from scratch since using libraries like Microsoft Botkit, or react-chatbot-kit requires major modification to SearchX-chat and may not be compatible with SearchX front-end. Additionally, following the Flux pattern, in which the SearchX front-end is implemented, support for updating the data and the view with bot messages is added to the front-end. Finally, the back-end is modified to forward the messages to the chatbot back-end so that the bot can monitor the ongoing conversation. In this way, ChatX is seamlessly integrated into SearchX.

The ChatX back-end contains the core functionality of the chatbot, namely the NLU capability. As stated in section 2.3, it is very difficult to build the NLU from scratch. So we use RASA Open Source with a pre-trained model to power ChatX. Comparing to other major platforms, including IBM Watson, Google Dialogflow, and Microsoft LUIS, RASA is not only the only open-source platform, but it also achieves comparable performance comparing to other platforms and the highest confidence score among all platforms [1]. We trained the NLU model with self-composed data since there is no publicly available conversational data set in the domain of restaurant finding and local attraction finding.

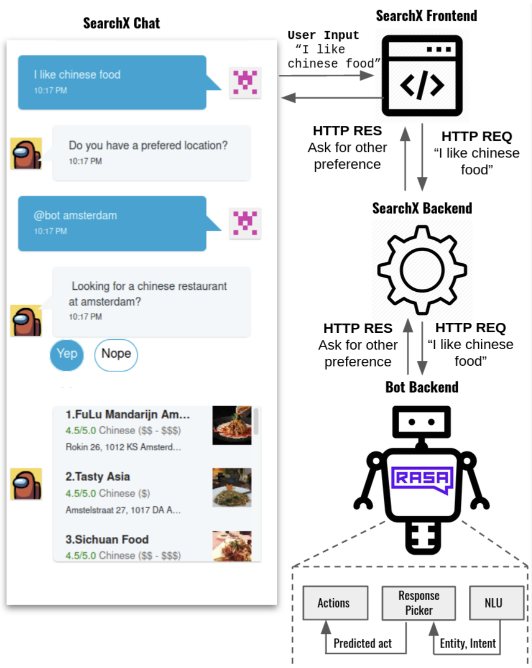
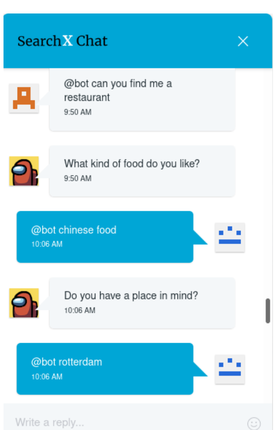
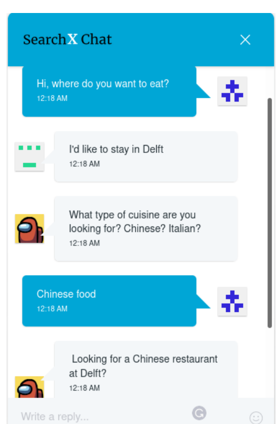


Figure 3: High-level Structure of ChatX

ChatX interacts with users in two ways: Firstly, as in Figure 4a, users can actively interact with ChatX by prefixing the message with "@bot." If the request is relative to the search task, ChatX will try to gather required information by asking questions and retrieve results if all key information requirements are satisfied. Secondly, ChatX will intervene when it successfully infers information relative to the search task from users' conversation, which is depicted in Figure 4b. There are two scenarios in this case: if the bot has all the required information, then it will retrieve the results. Otherwise, it will ask questions about the missing pieces of information.



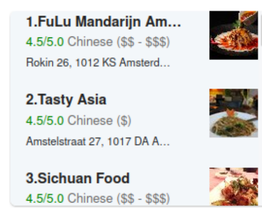
(a) User proactively interact with ChatX



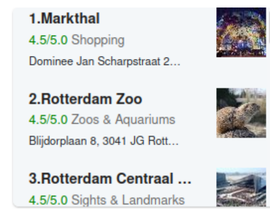
(b) User passively interact with ChatX

Figure 4: Two interaction modes of ChatX

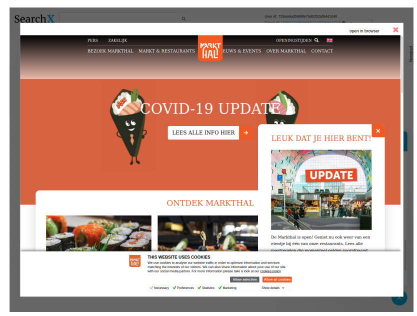
After ChatX has gathered all prerequisite information, it queries a Tripadvisor[2] REST API with the constraints as query parameters. The result is presented as a list of entries which consists of name, thumbnail picture, rating, type, price information(optional), and address as shown in Figure 5. Each entry is also clickable, and it will open the website of the restaurant or the local attraction in a SearchX view page as in Figure 5c for user to have more detailed information.



(a) Result for restaurant task



(b) Result for local attraction task



(c) Expanded view of result entry

Figure 5: Results returned by ChatX

4.3 Data Analysis

In the experiment, each group has the chance to experience both bot conditions: with a bot and without a bot, such that the two conditions were balanced among all participant groups. Since we have two small unpaired samples drawn from a non-normal distribution, following the procedure listed in [8], we chose the Mann-Whitney U test to compare the difference between the two conditions. We compute the p-value to determine whether there's a statistically significant difference between the two bot conditions. Additionally, we use the answers from the open-end questions to identify the desired or undesired behavior of the chatbot, which leads to future work.

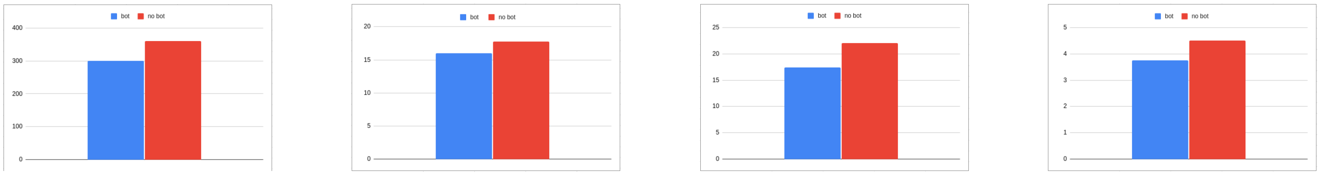
5 RESULTS

In this section, we first address the research question with the result from the experiment. Then, to better interpret the answer and shed light on future work, we also present users' impressions on ChatX.

5.1 Research Question: How chatbot affects users' collaborative experience

To answer the research, we present the results in two perspectives:

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



(a) completion time(secs.)* **(b) message count*** **(c) message length*** **(d) query count***

Figure 6: Objective measures of collaborative effort(* denotes that the different does not reach significant level where $p < 0.05$)

Objective measurement of collaborative effort. We measure four metrics that are related to participants' collaborative effort: task completion time, message count, message length, and query count. As illustrated in Figure 6, groups with bot have a lower mean value of all four metrics, which indicates that bot can reduce the effort required to complete the task. However, the p-values of these four metrics are all above 0.05 ($p_{completion\_time}$: 0.88, $p_{message\_count}$: 0.88, $p_{message\_length}$: 0.77, p_{query_count} : 0.25) , which means that the chatbot does not have a significant influence on participants collaborative effort.

Participants' perception of collaborative experience. we analyze the result of the post-task questionnaire to evaluate participants' perception of the collaborative experience. In Figure 7, it can be clearly seen that participants have a better collaborative experience with the bot. Especially, they believe chatbot makes it easier to share information, coordinate and communicate with their partners, and reach consensus. The differences are significant as the p-values are way lower than the threshold of 0.05. On the other hand, even though chatbot has an effect on improving participants' awareness and enjoyment during collaboration, it does not reach the significant level.

5.2 Users' Impression on ChatX

In the second and third parts of the questionnaire, we investigate participants' impressions of ChatX. In the second part, we asked eight yes or no questions about participants' opinions on predefined aspects. In Figure 8, the result shows that only 12.5% of the participants consider the chatbot distracting and annoying, 75% of the participants think that ChatX saves their time or gives them new ideas, and 87.5% of the participants are confident in the ChatX's returned result and believes ChatX provides them with new information. Moreover, all participants believe that ChatX has provided them useful information.

We also have two open-end questions as the third part of the post-task questionnaire. After filtering out non-informative feedback such as "no" or "it helps" we found that participants' opinion concentrates on the following aspects:

- If ChatX helped you in the task, how?
  - The list of advice given by ChatX is straightforward
  - It searches for me such that I do not need to search in the search engine
  - The options suggested by ChatX is exactly what I want
- If ChatX did not help you in the task, why?
  - sometimes it's not responsive
  - it interrupts the conversation, which is annoying
  - it keeps asking the same question

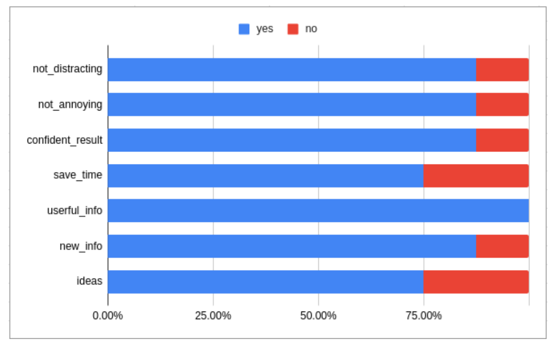


Figure 8: Participants' impression on ChatX

6 RESPONSIBLE RESEARCH

It is important for any research to follow responsible research principles. In this section, the implication of the principles is discussed from two perspectives: the research integrity in section 6.1 and research reproducibility in section 6.2.

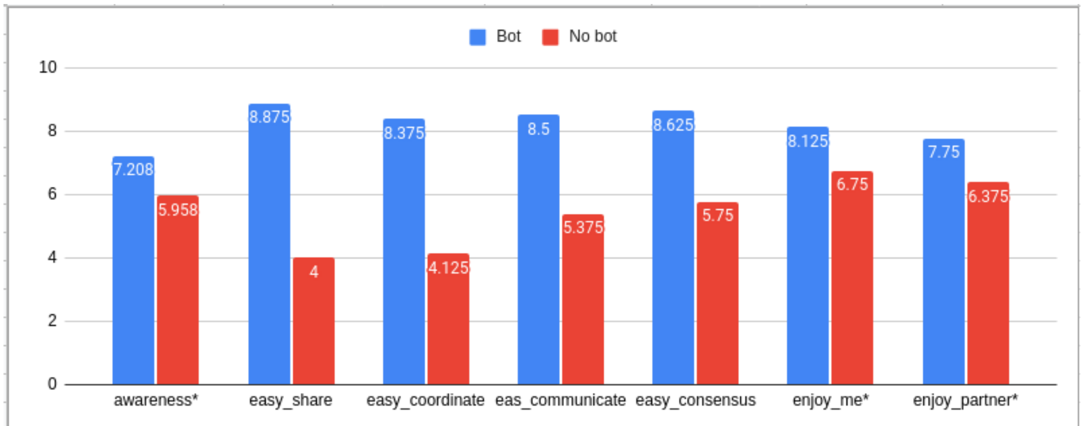
6.1 Research Integrity

This research does not violate research integrity reflected in the following aspects: We follow the Human Research Ethics guideline and fill in the checklist. All potential risks from 0 to 10 are answered with no. Moreover, the result and conclusion of this research are based on all collected data during the study. The original data and processed data are properly stored for future reference, which leaves no room for data manipulation. There are no conflicts of interest such as self-dealing, outside employment gifts, or owning stock. All related works that this research is built upon are quoted and cited.

6.2 Research Reproducibility

To maximize the reproducibility of the study, efforts of three aspects have been made: Firstly, all source code from the ChatX and the extensions of SearchX have been open-sourced and hosted on public repositories on Github. Hence, the project can be easily rebuilt. Secondly, the NLU model, together with its training data, pipeline configuration, and action scripts, are publicly accessible. Such that it can be reproduced by simply adopting the same model or retraining a similar model. Lastly, the study protocol is documented with detail in section 3.

However, since the project is built upon multiple open-source frameworks and libraries, there exists a slim risk that the exact version of the components becomes unavailable in the future. Using



	awareness*	easy_share	easy_coordinate	eas_communicate	easy_consensus	enjoy_me*	enjoy_partner*
Bot	7.208	8.875	8.375	8.5	8.625	8.125	7.75
No bot	5.958	4	4.125	5.375	5.75	6.75	6.375
p-value	0.102	0.0008	0.0008	0.0017	0.0109	0.2202	0.24121

Figure 7: Post-task response about collaborative experience with different bot conditions(* denotes that the different does not reach significant level where $p < 0.05$)

newer versions or alternatives may cause the chatbot to be broken or alter its behavior.

7 DISCUSSION

7.1 Research Question

From the results in section 5, we found that employing a chatbot on a collaborative search system does not significantly reduce the collaborative search effort. Whereas in [3], when a chatbot is used with a single-user search engine and a messaging platform, it reduces the need to search independently. A possible explanation is that the collaborative features of SearchX render the chatbot less useful. This leads to future work to comparing users' collaborative search effort with combinations of bot condition and *SearchX condition* (collaborative features on or off).

We found that the chatbot improves users' collaborative search experience. Especially it improves the collaboration experience, including sharing, coordinating, communicating, and reaching consensus. So, despite the fact that users' efficiency is not significantly improved, but the chatbot makes the process smoother and the collaboration less frictional on a collaborative search system.

7.2 Limitations

Implementation of ChatX. Unlike in study [3] where they employed Wizard-of-Oz methodology. We implemented ChatX in this study as a fully automated chatbot to aid the user during the collaborative search. However, due to limited resources, including time, training data, and NLP knowledge, ChatX is not sophisticated enough to be always responsive to any user requests. From section 5.2, we notice that it affects users' perception of their collaborative search experience.

Convenient samples. Due to the budget limitation, the participants of this research are recruited from friends and family members who have similar backgrounds and may have a certain bias in their opinion. Therefore, the result can not be generalized to represent the entire population that likely involves in a collaborative search.

Search Tasks. In the experiment, we use similar search tasks as in the study [3]. According to the definitions in [17], the two search tasks can be both categorized as leisure task which is utility-based, decision-making task. [17] also finds that user tends to have different behavior when conducting an academic search which is a more recall-oriented, information-gathering task. Hence, the result could be different when the participants collaborating on an academic search task.

8 CONCLUSIONS AND FUTURE WORK

A user study was conducted in this study to find out what effect does employ a chatbot as a search assistant has on users' collaborative search experience. We designed and implemented a fully automated chatbot and integrated it into the collaborative search system SearchX. We measured and surveyed users' collaborative search experience and found that employing a chatbot on a collaborative search system does not significantly reduce users' search effort. However, it makes sharing, coordinating, communicating, and reaching consensus easier and improves users' collaborative search experience.

The work presented in this paper can be improved by implementing a more sophisticated chatbot with better NLU capabilities. since the chatbot currently can not respond to all user requests and can be annoying due to its less intelligent responses. Furthermore, the study could have use more representative samples to make it more generalized. Besides improvements, new questions also arise from the study: (1) Will using chatbot reduce users' collaborative search effort when other collaborative features are turned off (2) effect of using a chatbot as search assistant on academic search tasks.

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