Comparative Study of Behavior and Experience in Collaborative and Independent Search: Post-print

Authors: Zhang Lu, Liu Chang, Zhang Pengyi

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Abstract

[Purpose/Significance] This study investigates the differences in users' search experience and interactive behavior when completing information search tasks in collaborative versus independent modes, attempting to understand the characteristics of collaborative information search behavior through comparative research, and providing insights for the design of collaborative search systems. [Method/Process] An experiment was conducted based on the interactive book retrieval platform CLEF-Social Book Search. A total of 16 independent participants and 18 collaborative participants were recruited to the laboratory to complete various types of book search tasks. A comparative analysis was performed on the search experience recorded through pre- and post-search questionnaires and the interaction behaviors recorded by the backend server during the search process. [Results/Conclusion] In terms of search experience, collaborative search participants provided more favorable evaluations of the experimental system's functionality, higher ratings for the system's aesthetics, robustness, and novelty, and demonstrated greater concentration in the experiment, but perceived it as more effortful. In terms of search behavior, compared to participants in independent mode, participants in collaborative mode made more decisions in goal-oriented tasks, especially decisions to delete books, suggesting that collaborative search participants engaged in more decision-making discussions and organization in the later stages of search. In exploratory tasks, collaborative participants had longer average decision time and first decision time than independent participants, possibly due to their higher engagement and more extensive discussions.

Full Text

Preamble

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A Comparative Study of Search Interactions and Experiences Between Collaborative and Individual Search

Zhang Lu[1], Liu Chang[2], Zhang Pengyi[2]
[1] National Science Library, Chinese Academy of Sciences, Beijing 100190
[2] Department of Information Management, Peking University, Beijing 100871

Abstract

[**Purpose/Significance**] This study investigates differences in user search experience and interaction behavior between collaborative and individual modes when completing information search tasks. Through comparative analysis, we aim to understand the characteristics of collaborative information search behavior and provide insights for collaborative search system design.

[**Method/Process**] Using the book interactive retrieval platform (CLEF-SocialBookSearch), we recruited 16 individual participants and 18 collaborative participants to complete various types of book search tasks in a laboratory setting. We conducted comparative analyses of search experiences recorded through pre- and post-search questionnaires and interaction behaviors logged by the backend server.

[**Results/Conclusions**] Regarding search experience, collaborative search participants evaluated the experimental system's functions more positively than individual searchers, rating the system's aesthetics, durability, and novelty higher, and demonstrating greater focus during the experiment, though they also reported higher mental effort. Regarding search behavior, compared to individual searchers, collaborative searchers made more decisions in goal-oriented tasks, particularly regarding book removal decisions, suggesting they engaged in more discussion and organization during later search stages. In exploratory tasks, collaborative searchers exhibited longer average decision times and longer time-to-first-decision than individual searchers, likely due to higher engagement and more extensive discussion.

Classification Number: G252.7
Keywords: collaborative information search, information behavior, user study

Introduction

Information search constitutes a vital component of human activity. Most existing theories, models, and systems for information search behavior assume independent searchers. However, with the development and popularization of information technology, collaborative information search involving multiple

participants has become increasingly common. In recent years, collaborative information seeking behavior has attracted growing scholarly attention, with researchers exploring how to optimize independent search systems to support multi-user collaborative search. Analyzing differences between collaborative and individual information search can help us understand collaborative search behavior and inform related theoretical research and system design.

Collaborative information search encompasses multiple modes, including same-time same-place, same-time different-place, different-time same-place, and different-time different-place collaboration [1]. This study focuses on the most common and communication-convenient mode: same-time same-place collaboration. Existing research on collaborative information search behavior has primarily examined differences in search output and interaction behaviors across various collaborative modes versus individual modes [2-5], with less attention paid to differences in search experience and interaction behavior—precisely the focus of this study.

Through experimental methods, we collected data on interaction behaviors and search experiences when individual users and collaborative groups used the same search system, comparing differences to explore characteristics of collaborative information search behavior and propose suggestions for supporting collaborative search system design.

For search behavior research, T.D. Wilson [6] distinguished between information seeking and information searching using a nested model, considering information seeking as the broader behavior of querying and obtaining information from various sources, while information searching represents a subset involving user interaction with computer-based information systems. Most information search behavior research has studied independent search scenarios, with collaborative search research still underdeveloped. However, findings from independent search research provide important reference points for indicator selection and research methods in collaborative search studies. Therefore, before empirically comparing collaborative and individual search differences, we first summarize existing research on both independent and collaborative search.

2 Literature Review

2.1 Independent Information Search Behavior and Experience

Independent search behavior has been extensively studied with numerous findings. This section reviews domestic and international research on independent search behavior. Yang Haifeng [7] summarized information behavior research in information retrieval from four perspectives: user types, search behavior categories, research methods, and practical applications. C. Liu, P. Qu, and T. Xu [8] summarized web search and user search behavior research in mainland China from 2008-2013 across three dimensions: search context, search behavior, and implications for system optimization. Zhang Yunqiu [9] reviewed complex information search behavior and exploratory search research, categorizing

studies into experimental and real-world environments. For experimental environment research, she summarized content across behavioral subjects, search tasks, search processes, cognition, and influencing factors. These reviews reflect that: (1) user search behavior is influenced by multiple factors such as personal characteristics and search task topics/types; (2) user search behavior can be characterized across multiple dimensions, including query formulation, click-and-browse behavior, and usefulness judgment of pages.

D. Kelly [10] categorized evaluation metrics for interactive information retrieval systems into four types: contextual variables, interaction variables, performance, and user subjective evaluation—providing a framework for describing and summarizing user search behavior research. Contextual variables include user characteristics (age, gender, etc.) and information need variables (search task features, domain knowledge, etc.). Interaction variables describe behaviors, performance refers to objective system output quality, and subjective evaluation refers to user assessments of search experience.

Most search behavior research focuses on analyzing relationships between contextual and interaction variables. Recent studies have emphasized detailed task type classification and its impact on search behavior and experience. For instance, An Wenxiu [11] studied exploratory medical information search behavior, subdividing exploratory tasks into hypothesis-driven and verification-driven searches. Yuan Hong and Li Qiu [12] examined how search tasks and user ability affect search behavior. Li Yuelin et al. [13] subdivided attributes of exploratory search tasks and explored their impact on search behavior. This study also selects search task type as a primary contextual variable to analyze its influence on search behavior.

Additionally, objective search performance and user self-assessment of search experience constitute important research content, with increasing studies discussing how contextual and behavioral variables affect these outcomes. For example, Liu Jian et al. analyzed relationships between user behavior and satisfaction [14]; Wang Ruojia and Li Yuelin evaluated health search engine usability from a user experience perspective [15]. User evaluations of search experience represent subjective assessments that reflect system effectiveness in supporting user searches. Therefore, this study also compares user search experiences across both modes to reveal how search mode affects subjective evaluations.

Independent search behavior research has established widely accepted methods and identified key research variables that can be applied to different user groups and contexts. Thus, when comparing collaborative and individual search, this study draws on independent search research approaches, analyzing how contextual variables (including search task type and search mode) affect user interaction behaviors (including query formulation, page clicking, and usefulness decisions) and user search experiences (task evaluation, engagement assessment, and system usability evaluation).

2.2 Collaborative Information Search Behavior Research

J. Foster [2] defined collaborative information seeking and retrieval research as the study of systems or practices enabling multiple individuals to cooperate during information seeking, searching, and retrieval. In recent years, scholars have conducted extensive research on collaborative information search behavior. Wu Dan and Qiu Jin [5] found that behavior patterns, cognitive impacts, and task types constitute three main research themes, with privacy protection and social environmental factors gaining increasing attention. Domestic research has focused on identifying motivational and behavioral factors affecting team collaborative search. For example, Liu Jia [16] found that team members' task cognition, organizational climate, communication environment, and project collaboration stages affect collaborative information query intentions and outcome perceptions. Xia Beibei [17] further discovered that division of labor and cooperation attitudes significantly affect collaborative information search intentions. Han Yi and Zhou Chang [18] identified factors affecting academic team collaborative information seeking, including cooperative information use, self-literacy, cooperation willingness, team atmosphere, and topic interest. Dai Jun and Guo Shixin [19] analyzed situational factors triggering collaborative information search after personal search failure, examining correlations between failure types, information source perspectives, time urgency, information importance, and search strategy changes.

Research on collaborative information search behavior characteristics primarily adapts interaction indicators from individual search research. Additionally, C. Shah [20] proposed metrics for evaluating collaborative search experience, including collaborative attitude, system usability, cognitive load, engagement, awareness, and emotion; interaction behavior metrics such as task completion time, chat record usage, number of bookmarks created, and questions generated; and metrics for measuring collaborative communication content and volume [21]. Empirical studies have compared collaborative and individual search differences in queries and retrieval effectiveness, finding that collaborative searchers use more diverse queries [22-23], search more topics and find more answers within the same timeframe (higher efficiency) [24], achieve better results and rate collaborative functions higher [25], and that dyadic collaboration promotes search process regulation and outcomes with shorter time, more search strategies [26-27].

Many factors affect collaborative information search experience and interaction behavior, including collaboration mode [22-23, 25], collaborative ability [28], task type [21, 23, 25, 28], and team awareness [30-31]. Some studies combine multiple factors to analyze collaborative search characteristics, such as analyzing social media usage proportions as collaborative search tools during travel planning stages [32]. Researchers have also examined emotional dimensions in collaborative search. Qiu Jin and Wu Dan [33] analyzed how collaborative ability and tasks affect emotional communication and change, finding that groups with stronger collaborative ability communicated more frequently and exhib-

ited more positive emotions. Yuan Hong and Zhao Yuxin [34] experimentally analyzed how task type, problem-solving ability, and intimacy affect task perception and emotional states, finding that task type affects task perception, problem-solving ability affects collaborative search experience, and collaborators with strong problem-solving abilities and close relationships show more interest in difficult tasks, with positive task perception and emotions enhancing collaborative retrieval effectiveness.

Collaborative search has multiple modes: synchronous/asynchronous, same-place/different-place, and can be categorized across dimensions including knowledge space, psychological space, cultural space, collaboration stage (sharing results vs. cooperative process), collaboration intensity (encounter/social/embedded/strategic), purpose (explicit/ambiguous), and system access level [3-4]. This study focuses on synchronous same-place collaborative information search. Additionally, while existing research has emphasized collaborative search effectiveness and emotional dimensions, systematic research on user-system interaction behavior and search experience remains limited—precisely the focus of this study.

3 Research Methods

3.1 User Experiment

This study employed an experimental method using the online search system provided by the Social Book Search Interactive Track of the Conference and Labs of the Evaluation Forum (CLEF) [35]. CLEF was originally established as an open evaluation platform for European language information retrieval and has become an internationally renowned public platform for information retrieval technology evaluation. This study selected its social book retrieval platform because it provides a browsing and purchasing system similar to Amazon, offering book introductions and user reviews but without price information. For all participants, it was a new experimental system that minimized interference from price information and system usage experience.

The experimental system pre-configured task types, sequences, specific task descriptions, and pre-/post-search questionnaires. Participants simply logged into the system and followed instructions to complete the experiment.

The experiment controlled for search mode across participants, with interaction behaviors recorded by the server and search experiences recorded via questionnaires. We recruited 34 students from Peking University through online BBS forums, including 29 undergraduates, 4 master's students, and 1 PhD student. Among them, 16 were individual search participants (7 male, 9 female), and 18 were collaborative search participants who formed teams voluntarily (9 dyads), including 16 females and 2 males. We did not restrict gender composition when recruiting collaborative dyads, aiming to recruit participants with natural collaborative work experience to minimize experimental interference. Possibly due to males having less collaborative search experience, only two composition pat-

terns emerged: female-female friend pairs and male-female romantic pairs (the two male participants each joined with their girlfriends), with no male-male friend pairs.

Since the experimental system's book information primarily involved English books in the humanities, to minimize interference from English reading ability and cultural background, we required participants to have strong English proficiency (English majors or passed CET-6) and major or double-major in humanities. Each collaborative dyad and each individual participant completed two search tasks.

The experimental system included two task types: Focused and Open, plus a specific-topic task. Task descriptions in Chinese were:

(1) **Focused Task**: Imagine you are participating in a week-long experiment on a deserted island with no people, TV, radio, or other distractions. You can only bring 5 books. Please search for and add 5 books you would like to read during your island stay to the shopping cart: a book about island survival; a book for learning something new; a book related to your personal interests; a book highly recommended by other users (based on ratings and reviews); and a book for leisure entertainment.

(2) **Exploratory Task**: Imagine you are waiting for a friend at a café/bar/airport/office. While waiting, you discover this website and explore it, searching for any books you find interesting, attractive, or relevant. Please search freely, and when you find interesting books, add them to the shopping cart. Stop searching when you feel bored.

(3) **Specific-Topic Task**: You are interested in Elizabethan era books (British monarchy, 1558-1603) and have already read George Garrett's *The Death of the Fox* and *The Succession*. You want to find other books on this topic, fiction or non-fiction. Please use any website interface to find one or more books meeting these criteria.

3.2 Search Experience and Interaction Variables

This study investigates differences between collaborative and individual information search in search experience and interaction. Before each search task, participants completed pre-search questionnaires assessing topic familiarity and anticipated task difficulty:

- Pre-search topic familiarity: "How familiar are you with this task's domain?" (1=Not at all familiar; 2=Not very familiar; 3=Somewhat familiar; 4=Very familiar)
- Pre-search task difficulty: "How difficult do you think this task is?" (1=Very simple; 2=Somewhat simple; 3=Somewhat difficult; 4=Very difficult)

Search experience describes participants' post-search perceptions of task comple-

tion, system functionality, and overall experience, measured through post-search questionnaires in three parts: task experience, functional evaluation, and system experience.

(1) Task Experience: - Post-search task difficulty: "How difficult was this task?" (1=Very simple; 2=Somewhat simple; 3=Somewhat difficult; 4=Very difficult) - Post-search topic familiarity: "How familiar are you now with this task's domain?" (1=Not at all familiar; 2=Not very familiar; 3=Somewhat familiar; 4=Very familiar) - Post-search completion satisfaction: "How satisfied are you with your completion of this task?" (1=Very dissatisfied; 2=Somewhat dissatisfied; 3=Somewhat satisfied; 4=Very satisfied) - Post-search information richness: "Was there sufficient book information on the website?" (1=I found almost no relevant book information; 2=I found not much relevant information; 3=Yes, there was quite a lot; 4=Yes, there was a great deal)

(2) Functional Evaluation: Participants rated 13 system functions on a 5-point usefulness scale (1=Not at all useful to 5=Very useful), including: shopping cart annotations, finding similar books, browsing book lists, browsing related topics, book description information, publication information, book reviews, book tags, search box, search facets, search history, search results list, search topic scope selection.

(3) System Experience: We measured participants' system usage experience using H.L. O'Brien & E.G. Toms' engagement scale [36], including six dimensions: interface aesthetics, durability, focus, involvement, novelty, and perceived usability. Participants rated multiple descriptive statements for each dimension on a 1 (Disagree) to 5 (Agree) scale.

For interaction behavior, we focused on browsing and decision-making behaviors of collaborative and individual groups, calculated from backend server logs:

- Task duration: Time from clicking "Task Start" to "Task Complete"
- Book addition frequency: Number of decisions to add books to cart
- Book deletion frequency: Number of decisions to remove books from cart
- Books in cart: (Additions) - (Deletions)
- Total decisions: (Additions) + (Deletions)
- Average decision time: Task duration / Total decisions
- Time to first decision: Duration from "Task Start" to first book addition
- First decision time proportion: Time to first decision / Task duration
- Number of queries: Queries entered and searched during task
- Average query length: Average words per query = Total words in all queries / Number of queries
- Unique query terms: Number of non-repeated words across all queries
- Page-turning frequency: Clicks on "Previous" or "Next" page
- Tag filtering frequency: Uses of topic tags or user tags to filter scope/results
- Similarity search frequency: Uses of similar authors, user tags, topics, or titles

- Interface switching frequency: Switches between “Browse,” “Search,” and “Cart” interfaces
- Book detail views: Clicks to view book details
- Book facet views: Clicks on book detail facets

4 Results

Before data analysis, we conducted normality tests on all indicators. For normally distributed variables, we used independent samples t-tests to compare collaborative and individual modes; for non-normally distributed variables, we used Mann-Whitney U tests. We first compared mean ratings of topic familiarity and task difficulty between groups, finding no significant differences—thus excluding these as confounding factors for subsequent analyses.

4.1 Differences in Search Experience Between Collaborative and Individual Search

For search experience, we first compared evaluations of system function usefulness, then compared system experience ratings.

Functional Evaluation: After completing searches, the CLEF system asked participants to rate 13 functions. Mann-Whitney tests revealed significant differences in 4 functions, with collaborative participants rating them higher than individual participants (see): related topic browsing, search topic scope selection, search box, and book review information. Although only 4 functions showed significant differences, collaborative participants generally demonstrated higher acceptance of system functions, possibly because communication and discussion made them more receptive.

System Experience: Using O’Brien & Toms’ engagement scale [36], we found substantial differences between groups (see):

(1) **Interface Aesthetics:** Collaborative participants rated website aesthetics, graphic usage, visual appeal, and architecture significantly higher than individual participants, though website attractiveness ratings did not differ significantly. This suggests the interface design appealed more to collaborative searchers, or that collaborative searchers preferred the experimental system’s interface design.

(2) **Durability:** No significant differences emerged in evaluations of exploration value, success, plan adherence, or learning. However, collaborative participants showed slightly higher (non-significant) likelihood of recommending the system, indicating somewhat higher acceptance.

(3) **Focus:** Collaborative and individual participants differed significantly in time perception and exploration immersion, with collaborative participants reporting faster time passage and greater immersion. However, no differences appeared in feelings of being isolated from surroundings, time

management, or self-control. This suggests collaborative participants better adapted to the experimental environment and focused more intently on tasks.

(4) **Involvement:** Collaborative participants rated exploration task involvement, participation, and interest significantly higher than individual participants, indicating exploratory tasks were more engaging for collaborative searchers or that collaborative participants showed greater interest in exploring new, unfamiliar systems and information.

(5) **Novelty:** While curiosity about exploration and content did not differ significantly, collaborative participants showed significantly higher task interest than individual participants.

(6) **Perceived Usability:** Collaborative participants reported greater mental effort than individual participants, likely because collaboration and discussion required more coordination and exploration of system functions and content, increasing perceived effort while also enabling more comprehensive function exploration and better search experience.

No significant differences appeared in frustration, discouragement, website confusion, annoyance, mental burden, process control, or unmet needs.

4.2 Differences in Interaction Behavior Between Collaborative and Individual Search

This section compares user interaction behaviors across modes, first across all tasks, then by task type. Results appear in .

Across all tasks, no significant differences emerged in interaction behaviors between collaborative and individual participants in any measured variables, including task duration, decision frequency, and average decision time. However, this may mask task-type differences.

In Focused Tasks: Collaborative and individual participants differed significantly on two variables: decision frequency (M_{collaborative} = 9, M_{individual} = 5) and book deletion frequency (M_{collaborative} = 2, M_{individual} = 0). Collaborative participants made more decisions overall, particularly removing books from carts, though addition frequencies did not differ. Collaborative participants typically removed books from carts about 2 times, while individual participants rarely did so. This suggests that in focused tasks, collaborative dyads engaged in more organization and selection, possibly adding books tentatively when opinions diverged, then discussing final selections and removing books later. Individual participants typically selected books according to their own criteria with minimal post-search reorganization.

In Exploratory Tasks: Collaborative participants spent significantly longer on average decision time and time-to-first-decision than individual participants, though total task duration and first-decision time proportion did not differ sig-

nificantly. This indicates collaborative participants spent more time seeking and understanding information before each decision, likely requiring more alignment on search methods, information interpretation, and evaluation criteria. Longer preparation before first decisions also occurred, but because total task duration was also longer, the proportion did not differ significantly.

5 Conclusion and Discussion

This study has limitations. First, the sample was homogeneous. Because the experimental system was an English book retrieval system, we required humanities backgrounds and English proficiency, and all participants were Peking University students, limiting generalizability. Second, system limitations existed. To isolate the search process from price and experience confounds, we used the CLEF book interactive retrieval system. However, the all-English interface created difficulty that may have affected results, and the book information search context limits application scope.

Future research could address these limitations by: (1) studying more diverse samples (different disciplines, industries, families) to examine how group characteristics affect search behavior; (2) investigating collaborative versus individual search differences using Chinese-language systems across various information search contexts.

Findings indicate that collaborative searchers evaluate new system functions more positively, show greater engagement and interest in search tasks, and demonstrate higher acceptance of new systems. This suggests collaborative search modes could enhance user engagement and acceptance in system testing, experiments, and educational contexts. In focused tasks, collaborative searchers make more decisions, particularly deletions, showing a collect-then-filter strategy. Therefore, collaborative search systems should include features supporting information selection, marking, filtering, and organization to improve collaborative search efficiency. In exploratory tasks, collaborative searchers do not differ in decision frequency but spend longer per decision, indicating they explore more functions and information, resolve disagreements before decisions, and thus make more accurate decisions with less subsequent reorganization. Therefore, exploratory search tasks can help collaborative searchers fully explore and learn systems. To better support collaborative search, systems should design efficient search decision aids enabling timely sharing of suggestions and ideas during information finding and filtering.

References

[1] ELLIS C, GIBBS S, REIN G. Groupware: Some issues and experience[J]. Communications of the ACM, 1991(34): 38-58.

[2] FOSTER J. Collaborative information seeking and retrieval[J]. Annual review of information science & technology, 2006, 40(1): 329-356.

[3] HAN Yi. Research on the connotation and classification of collaborative information seeking and retrieval[J]. Information Science, 2011, 04: 600-604+608.

[4] GOLOVCHINSKY G, QVARFORDT P, PICKENS J. Collaborative information seeking[J]. Computer, 2009, 42(3): 47-51.

[5] WU Dan, QIU Jin. Review of foreign research on collaborative information retrieval behavior[J]. Journal of Library Science in China, 2012, 38(6): 100-110.

[6] WILSON T D. Models in information behaviour research[J]. Journal of documentation, 1999, 55(3): 249-270.

[7] YANG Haifeng. Review of current research and development trends of user behavior in information retrieval[J]. Library and Information Service Knowledge, 2015(6): 79-88.

[8] LIU C, QU P, XU T. Research on web search and user search behaviors in mainland China. DU J, Zhu Q, Koronios Q. (Eds.) Library and information science research in Asia-Oceania: theory and practice[M]. Hershey, PA: Information science reference, 2014: 45-60.

[9] ZHANG Yunqiu. Review of foreign exploratory search behavior research[J]. Library and Information Service, 2014, 58(11): 6-12.

[10] KELLY D. Methods for evaluating interactive information retrieval systems with users[J]. Foundations & trends® in information retrieval, 2009, 3(1-2): 1-7.

[11] AN Wenxiu. Research on exploratory medical search behavior based on log and cognitive analysis[D]. Changchun: Jilin University, 2014.

[12] YUAN Hong, LI Qiu. Research on the impact of search tasks and search ability on user exploratory search behavior[J]. Library and Information Service, 2015(15): 94-105.

[13] LI Yuelin, FAN Zhenjia, SUN Xingming. Research on the relationship between exploratory search task attributes and information search behavior[J]. Information and Documentation Services, 2017(1): 54-61.

[14] LIU Jian, LIU Yiqun, MA Shaoping, et al. Research on the relationship between search engine user behavior and user satisfaction[J]. Journal of Chinese Information Processing, 2014, 28(1): 73-79.

[15] WANG Ruojia, LI Yuelin. Usability evaluation of health search engines based on user experience[J]. Library and Information Service, 2016, 60(7): 92-102.

[16] LIU Jia. Research on collaborative information seeking and retrieval behavior mechanisms in enterprise project teams[D]. Chongqing: Southwest University, 2014.

[17] XIA Beibei. Research on mechanisms and influencing factors of collaborative information search behavior in project teams[D]. Nanjing: Nanjing University of Science and Technology, 2017.

[18] HAN Yi, ZHOU Chang. Empirical research on influencing factors of collaborative information seeking and retrieval behavior in academic teams[J]. Journal of the China Society for Scientific and Technical Information, 2015(4): 432-448.

[19] DAI Jun, GUO Shixin. Analysis of situational factors triggering collaborative information search behavior—Based on university students' personal search failure scenarios[J]. Library and Information Service Knowledge, 2016(5): 62-72.

[20] SHAH C. Evaluating collaborative information seeking: synthesis, suggestions, and structure[J]. Journal of information science, 2013, 40(4): 460-475.

[21] CAPRA R, SAMS B, SELIGSON P. Self-generated versus imposed tasks in collaborative search[C]//Proceedings of the 2nd workshop on Collaborative Information Seeking (CIS): workshop at the meeting of the American Society for Information Science and Technology. USA: American society for information sciences silver springs, 2011: 1-4.

[22] SHAH C, GONZÁLEZ-IBÁÑEZ R. Evaluating the synergic effect of collaboration in information seeking[C]//Proceeding of the international ACM SIGIR conference on research and development in information retrieval. USA: ACM, 2011: 913-922.

[23] YUE Z, HAN S, HE D. An investigation of the query behavior in task-based collaborative exploratory web search[J]. Proceedings of the American society for information science & technology, 2014, 50(1): 1-10.

[24] DINET J, VIVIAN R. The impact of friendship on synchronous collaborative retrieval tasks in the primary school[J]. British journal of educational technology, 2011, 43(3): 439-447.

[25] QIU Jin, WU Dan. Research on user collaborative information retrieval behavior and system evaluation—From the perspective of task type and collaborative ability[J]. New Technology of Library and Information Service, 2012(9): 62-68.

[26] LAZONDER A W. Collaboration on web search behaviour and search outcomes[J]. British journal of educational technology, 2005, 36(3): 465-475.

[27] WU Tong, ZHANG Ziran, FU Ting, et al. Review of experimental research on collaborative information retrieval behavior[J]. Library and Information Service, 2016(5): 125-132.

[28] WEI Li. Research on collaborative information search behavior[D]. Changchun: Jilin University, 2016.

[29] WU Dan, QIU Jin. Cognitive research in collaborative information retrieval behavior[J]. Journal of the China Society for Scientific and Technical Information, 2013, 32(2): 125-137.

[30] SHAH C, MARCHIONINI G. Awareness in collaborative information seeking[J]. Journal of the American Society for Information Science & Technology, 2010, 61(10): 1970-1986.

[31] PAUL S A, REDDY M C. Understanding together: Sensemaking in collaborative information seeking[C]//Proceedings of the 2010 ACM conference on computer supported cooperative work. USA: ACM, 2010: 321-330.

[32] FARDOUS J, DU J T, CHOO R, et al. Exploring collaborative information search behavior of mobile social media users in trip planning[C]//Proceedings of the iConference 2017. USA: iSchool, 2017: 435-444.

[33] QIU Jin, WU Dan. Research on emotion in collaborative information retrieval behavior[J]. Library and Information, 2013(2): 105-110.

[34] YUAN Hong, ZHAO Yuxin. Research on user task perception and emotional state in collaborative search behavior[J]. Library and Information Service, 2015, 59(17): 89-98.

[35] KOOLEN M, BOGERS T, GADE M, et al. Overview of the CLEF 2016 social book search lab[C]//Proceedings of the 2016 international conference of the cross-language evaluation forum for European languages. Berlin: Springer, 2016: 351-370.

[36] O'BRIEN H L, TOMS E G. The development and evaluation of a survey to measure user engagement[J]. Journal of the American Society for Information Science & Technology, 2014, 61(1): 50-60.

Author Contributions: - ZHANG Lu: Data collection, cleaning, analysis, initial draft writing - LIU Chang: Research design and guidance, paper revision - ZHANG Pengyi: Research design and guidance, paper revision

Note: Figure translations are in progress. See original paper for figures.