Investigation on Dynamics of Group Decision Making with Collaborative Web Search

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ABSTRACT

In this paper, we present results of investigation on the dynamics of group decision making –*how people discuss and make a decision*– with collaborative web search. Prior works proposed systems that support group decision making with web search but have not examined the influence of discussion behaviors especially on the satisfaction levels with the final conclusion. In this study, we conducted a set of experiments to observe discussion behaviors and the consequent satisfaction with the conclusion using our experimental system and a set of questionnaires. The task for each participant was to make a decision on a restaurant. Our primary results revealed (1) the similar activities across all groups at the beginning and the end of the group discussion, (2) a lack of correspondence between the satisfaction with the conclusion and the time spent to reach the conclusion, and (3) the presumption that a member who actively engaged in the activities that were visible for the other members was likely to be voted as a leader in the group discussion beyond the discussion. Finally, we discussed how to implement intelligent systems that aid group decision making.

CCS CONCEPTS

• **Human-centered computing** → **Computer supported cooperative work**; • **Information systems** → *Collaborative search*; Search interfaces;

KEYWORDS

Group decision making, Collaborative web search, Dynamics

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1 INTRODUCTION

In the modern society, there are countless situations that a group of people needs to make a decision while involving in a group discussion and information searching, e.g., vacation destinations, movies, or restaurants. Recent decades have witnessed the growth in popularity of "collaborative web search", a type of web search conducted by group members to achieve specific purposes including decision making. According to a recent survey with 167 participants regarding the experience with collaborative web search, half of the participants reported that they searched for information on websites together with friends at least once a month [5]. Unlike individual decision making, the group decision making is rather challenging since each individual member might have different preferences or interests. Numerous user-interfaces [2, 3, 6, 7] and algorithms for opinion summarizing [4, 9, 11], hence, have been developed to support collaborative web search. These studies showed that supporting discussions through information sharing or opinion summarizing could lead to efficient web search and satisfied conclusions.

However, the "dynamics" of group decision making with collaborative web search has not been clarified yet. In other words, the questions, *how group members proceed discussion*, *how group members use Web search*, and *how group members lead a satisfied conclusion*, have not been answered. Indeed, the dynamics could play an important role in collaborative web search; for instance, one's searching behavior (e.g., searching activity, involvement in discussion, or satisfaction in a conclusion) might be influenced by other

members' opinions or by any shared information. Understanding such dynamics would be an essential key to improving the development of an intelligent system that aids collaborative web search recommending useful information and facilitating group decision making at a right moment. Although previous works have verified the effectiveness of the proposed methods for sharing search results and for summarizing opinions among members, unfortunately, the dynamics of group discussion have not been sufficiently investigated yet.

To investigate the dynamics of group decision making, we conducted a set of experiments with eight groups of three members and observed how members carried out the group discussion with collaborative web search until a group decision was made, and the level of satisfaction with the decision was rated by participants. In particular, we mainly focused on the following items.

(1) How group members carry out the group discussion with collaborative web search.
(2) How dynamics of group decision making are associated with members' satisfactions with the conclusions.
(3) What kind of role each member implicitly plays.

2 RELATED WORK

Studies on supporting systems for group decision making can be broadly categorized into two main research fields: (1) user interface [2, 3, 6, 7] and (2) opinion summarization [1, 4, 9, 11, 13]. In general, user-interface-oriented research assumes that users conduct web search concurrently with discussion, while opinion summarization-oriented research is based on the scenario that group members firstly search for information independently and then a decision is made succeeding a group discussion based on the individually searched information.

Collaborative web search platform has been recently developed. SearchTogether is a prototype user-interface allowing group members to perform collaborative web search remotely in either synchronous or asynchronous manner [6]. The interface of SearchTogether provides functions for sharing information such as chat, history of search queries, and bookmarked web pages, allowing a smooth collaborative web searching. Ohchige et al. proposed a method to address the convergence of searching topics in mobile collaborative web search scenario [7]. The method automatically suggests searching queries to group members enabling the feasibility to control the convergence and divergence of searching topics, resulting in a smooth group decision making.

A variety of opinion summarization algorithms has been proposed to combine individual decisions to make a group decision. Saaty proposed a opinion summarization method for supporting group decision making by using AHP (Analytic Hierarchy Process [8]), which selects the most suitable item from the set of items composed of multiple elements [9]. Koshiba et al. extended the AHP method by introducing Negotiation Meta Information, a criterion to measure the subjective confidence of each group member on the selected items [4]. Opinion summarization can also be done by using the technique of group recommendation based on collaborative filtering [1, 11, 13]. More recently, Choicla was proposed to support group decision making using group recommendation techniques, and its competency was comparative with existing group decision support systems.

Many research in recent years also focused on the role of each individual in collaborative web search. In a previous study by Shar et al., two types of roles in collaborative web search were defined: Gatherer and Surveyor [10]. Gatherer is responsible for collecting the task-corresponding web pages, while Surveyor is responsible for collecting a variety of web pages regardless of the correspondence to the task. The researchers also proposed a search ranking algorithm tailored to the roles. Following the concept of Gatherer and Surveyor, Yamamoto et al. analyzed how search behaviors of group members with respective roles were affected by search behaviors of themselves and other members [12]. The study suggested that the influence of other members is contingent upon the assigned role. However, the work focused merely on a recall-oriented task in which a group of member search for information exhaustively together, accordingly, the implication of the discovery on decision-making task is still inconclusive.

It is noticeable that the usefulness and effectiveness of the proposed approaches were deliberately studied in previous works, however, the dynamics of group decision making have not been fully explored or discussed. In fact, it is highly possible that an individual might have an altered opinion when observing behaviors of other members. Consequently, we aim to gain more insights on the dynamics of group decision making with collaborative web search and the influence of role, focusing on a decision-making task.

3 EXPERIMENT

The experiments were conducted using our own in-house system developed to record activities of participants undergoing a group decision-making task with collaborative web search.

3.1 Participants

In this work, 24 undergraduate and graduate male students at Osaka University were recruited and categorized into eight groups of three members referred as A, B, ..., and H; all group members were acquaintances.

3.2 Task

The participants were instructed to search for a restaurant to go together with the other group members. The description of the task is as follows:

> "In this weekend, you will have a business trip in Tokyo. You will have free time on Saturday night, and you desire to go to a restaurant with your group members. Now, please decide a restaurant to go using our experimental system. The hotel you will stay during this business trip is located in Shinjuku".

The information source of restaurants in this experiment was prepared using GURUNAVI API[1].

[1] http://api.gnavi.co.jp/api/index_e.html. This API provides various and abundant information of restaurants in Japan such as location, price, menu, or review comments.

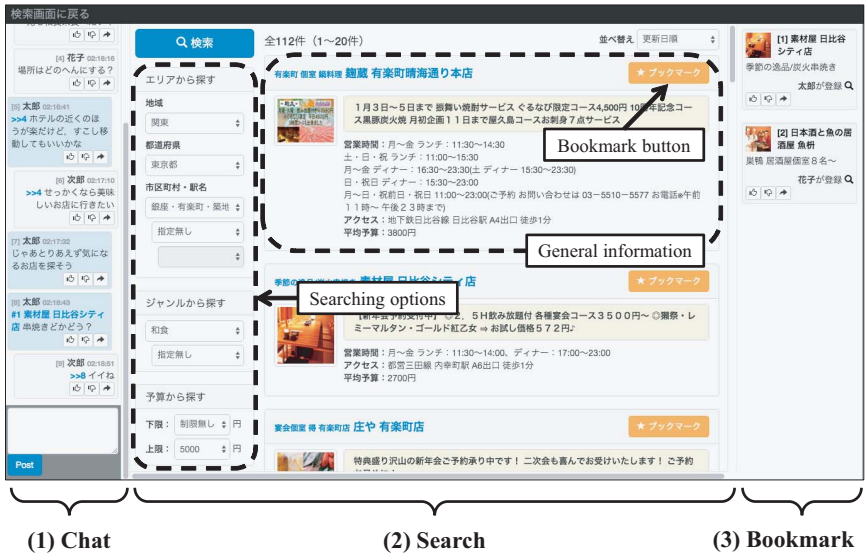

Figure 1: The interface of the experimental system. The left side is a space for chatting (1). The middle space is for searching restaurants (2). The right side shows the list of bookmarked restaurants.

3.3 Experimental setting

In the experiment, a member was instructed to perform the task separately and avoid oral communication in a physical space. The only communication channel was the chatting function provided in our experimental system. As a result, data of user behaviors can be digitally recorded. The other benefit was to exclude any effects of information that cannot be easily interpreted in the digital space (e.g. facial expression, gestures, operation tones of keyboards) on the above data as our ultimate goal is to analyze how the behaviors of a participant influence the behaviors of others.Note that our experimental setting was designed in accordance with the previous studies on remote collaborative tasks [6, 12].

3.4 Interface for collaborative web search

Figure 1 shows the interface of the experimental system, which was implemented in reference to the previous research by Yamamoto et al. [12]. This interface works on a web browser and has three key functions as follows.

(1) Chat: This function enables participants to chat. Chatting space is shown on the left side of Figure 1. All messages are shared among group members in real time. Participants can react to a message using one of three options: Like, Dislike, and Reply.

(2) Search: This function allows subject to perform search activities. Based on the search queries entered in searching options (appearing on the left side of (2) Search space in Figure 1), the first 20 search results, together with brief information of the restaurants (gathered in advance using GURUNAVI API), are shown in the search space located in the the middle of Figure 1, while the other results can also be navigated. By clicking on a search-result item, a participant can view more information of the restaurant. Furthermore, a bookmark button is provided for each search-result item allowing participants to share the favorite restaurants with other members via the bookmark list ((3) in Figure 1).

(3) Bookmark: This function displays the bookmarked restaurants in real time. The Bookmark space is located on the right side of Figure 1. Similar to (1) Chat, participants can react to a bookmarked item using one of three options: Like, Dislike, and Forward. By clicking on a designed button, a reference to the restaurant appears in the (1) Chat space.

3.5 Procedure

For each group, the experiment was conducted in the following procedure.

(1) Informed consent: Prior to the experiment, participants signed the informed consents to authorize the use of the recorded activity logs.

(2) Pre-questionnaire: Participants completed a questionnaire regarding the experience of using collaborative web search, the expected roles of each group member in the forthcoming discussion such as "who do you think will be a leader?", and the preference of restaurants.

(3) Practice: To avoid any effects by unfamiliarity to the system, participants listened to the guidance of system usage and then practiced by searching for preferred restaurants nearby the current residences.

(4) Main decision-making task: Next, participants performed the main group decision-making task as explained in Section 3.2. During this task, time constraint was not imposed.

(5) Post-questionnaire: Following the main task, participants took another questionnaire to assess the satisfaction with the conclusion (*"Were you satisfied with the conclusion?"*), the sense of accomplishment from sufficiently searching (*"Did you search restaurants well enough to make a decision?"*), the sufficient discussion (*"Did you discuss with others well enough to make a decision?"*), the sufficient opinion expression (*"Did you express your opinions well enough in the discussion?"*), and the reflection of opinions on the

Table 1: Periods of time until a decision was made (t_a) and until the conclusive restaurant was firstly bookmarked (t_b).

Group	t_a	t_b	$t_a - t_b$
A	43:37	13:40	29:57
B	37:33	05:08	32:25
C	38:05	07:15	30:50
D	48:19	29:35	28:44
E	10:07	04:02	06:05
F	48:38	22:05	26:33
G	75:54	63:43	12:11
H	20:24	14:36	05:48

conclusion (*"Do you think the conclusion was reflected by your opinion?"*), on the 5-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree). In addition, participants answered the question of the role of group members in the discussion, *"Who played a leading role in your perspective?"*.

4 RESULT AND IMPLICATION

In this section, we present the analysis of activity logs and the satisfaction with a conclusion based on the post-questionnaire. The definition of activity logs is firstly explained, followed by the summary of acquired data, and the representative cases of the observed dynamics of group decision making.

4.1 Definition of activity logs

Fours types of activity logs are taken into account: *search*, *view*, *chat*, and *bookmark*. Based on the interaction with the experimental system of a participant, an action is defined as: *search* if the participant executes a search with searching options and a page transition to the next collection of results; *view* if the participant views a restaurant page, including making a page transition to food menu or location on the same restaurant page; *chat* if the participant posts a chat message; *bookmark* if the participant bookmarks a restaurant.

4.2 Statistics of activity logs

Table 1 shows the period of time spent until a group decision was made (defined as t_a) and the period of time spent until the conclusive restaurant was firstly bookmarked in the experimental system (defined as t_b).

The difference of t_a and t_b indicate the period of time since the conclusive restaurant was firstly bookmarked until the group members made the decision. As can be seen, $t_a - t_b$ is longer than t_b in five out of eight groups, implying that even if group members could find a good candidate at an early stage of the discussion, they still spent longer time in searching or discussion to ensure that the restaurant would be optimal item for all members.

Interestingly, group G spent the longest time until the conclusive restaurant was initially bookmarked (63 minutes 43 seconds) but spent a relatively short time to make a decision afterward; a plausible reason was that they might already spend enough time in searching and discussing. Similarly, group E and H also spent a shorter time to make a decision after finding a good candidate.

Table 2: Statistics of activity logs in each group ((x, y, z) represents the amounts of activity logs of member #1, #2, and #3 in each group).

Group	Search	View	Chat	Bookmark
A	53	138	84	4
	(23, 11, 19)	(73, 35, 30)	(29, 32, 23)	(3, 0, 1)
B	35	233	83	8
	(8, 14, 13)	(61, 81, 91)	(35, 12, 36)	(2, 2, 4)
C	52	221	82	8
	(16, 20, 16)	(73, 76,72)	(19, 38, 25)	(3, 2, 3)
D	66	216	77	26
	(11, 13, 42)	(100, 56, 60)	(14, 31, 32)	(1, 5, 20)
E	10	21	46	1
	(4, 4, 2)	(7, 12, 2)	(12, 15, 19)	(0, 0, 1)
F	21	100	143	8
	(8, 6, 7)	(42, 27, 31)	(40, 43, 60)	(2, 2, 3)
G	82	140	186	19
	(27, 40, 15)	(50, 53, 37)	(77, 78, 31)	(8, 9, 2)
H	34	41	104	9
	(12, 11, 11)	(8, 14, 19)	(35, 33, 36)	(2, 5, 2)

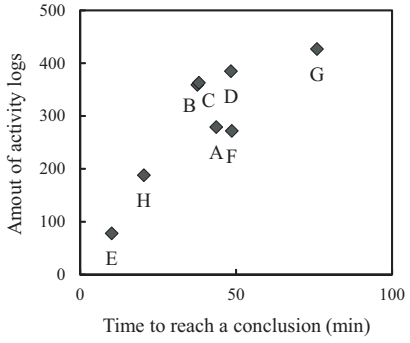

Figure 2: The length of time to make a decision (t_a) and the amount of activity logs of all groups.

Table 2 describes the statistics of activity logs of all members in each group. Also, Figure 2 illustrates the relationship between the period of time to make a decision and the amount of activity logs for all groups. We found that the time required for group decision making was highly correlated with the amount of activity logs of group members ($r = 0.85, p < 0.01$ calculated by Pearson's product-moment correlation analysis), implying that group members kept engaging in the constant amount of these activities regardless of time spent until making a group decision.

4.3 Responses to questionnaires

The answers of participants to the post-questionnaire are summarized in Table 3. Out of 24 participants, 23 participants scored 4 or 5 points and only 1 participant scored 3 points to the question item "Were you satisfied with the conclusion?" ($mean = 4.50, s.d. = 0.59$). This suggests that most participants were satisfied with group decision making. The participants also reported that "We could find out a restaurant to where every member wants to go", "I did not compromise with the decision making", or "Opinions of every member

Table 3: Distributions of answers to the post-questionnaire (the answer scale represents 1: disagree – 5: agree).

Question item	Score				
	5	4	3	2	1
I'm satisfied with conclusion	13	10	1	0	0
I searched restaurants well	4	9	6	4	1
I discussed with others well	9	11	3	1	0
I claimed my opinion well	8	14	2	0	0
My opinion reflected conclusion	14	5	5	0	0

seem to be reflected on the conclusion" inferring the reasons for high-score assessments.

There were 13 participants who scored 4 or 5 points to the item "Did you search restaurants well enough to make a decision?" ($mean = 3.46, s.d. = 1.10$). A participant who rated 3 or less points revealed that he spent most of the time in chatting with other members. According to the pre-questionnaire, he had no prior experience of collaborative web search suggesting that he might not be familiar with chatting and searching simultaneously. Another low-point-evaluating participant claimed that the system did not provide sufficient information of restaurant, and there was an evidence from the pre-questionnaire that he searched for restaurants on some occasions (at least once a month) with a strategy to compare the search results from multiple websites. There was another participant scoring lower point reported that he had no concern on the restaurant to go, and the analysis of pre-questionnaire suggested that he was rather unfastidious when deciding a restaurant to go with group members.

Concerning to the question item "Did you discuss with others well enough to make a decision?", 20 participants rated 4 or 5 points ($mean = 4.17, s.d. = 0.82$). Underlying reasons include the intensive discussion that led the satisfied conclusion and the enthusiastic reaction of other members to the proposals. In contrast, one of the participants who rated 3 or less points mentioned to the exhausting period of time to make a group decision, while some reported that since a targeted restaurant genre had been decided at the early stage of the experiment, the domain for searching was shrunk resulting in fewer discussion activities.

With respect to the items "Did you express your opinions well enough in the discussion?" and "Do you think the conclusion was reflected by your opinion", 22 and 19 participants rated 4 or 5 points respectively ($mean = 4.25, 4.38, s.d. = 0.61, 0.82$). The primary reason behind the ratings was that they felt free to suggest their opinions, or that the restaurant to their preference was finally selected. On the contrary, those who rated 3 or less points reported that the discussion was dominated by other members or that they mainly complied with opinions of the others.

Table 4 shows the number of votes obtained with the question item "Who played a leading role in your perspective?". Except for group C, all groups had one member who received at least 2 votes. Based on participants' answers to the post-questionnaire, those who engaged more in summarizing opinions of group members, in the group discussion, and in suggesting and bookmarking a plenty of restaurants, were likely to be voted as leaders.

Table 4: The number of times participants were voted as a leader in the post-questionnaire.

Group	Member #1	Member #2	Member #3
A	3	0	0
B	2	0	1
C	1	1	1
D	0	2	1
E	0	0	3
F	0	2	1
G	0	3	0
H	0	3	0

4.4 Dynamics of group decision making

In this subsection, we present an analysis of the time-varying distribution of participants' activity logs recorded on the experimental system. The dynamics of actions and consensus were examined. Hereby, we select three groups (A, C, and H) as representatives to present based on the lengths of the task performing and the leader voting results, while the recorded data of the other groups are available online[2].

(1) Group A: This group spent the third longest time (about 43 minutes) to reach the final conclusion, whereas the restaurant that was finally selected as the conclusion was initially bookmarked at an early stage of the discussion (at the 13th minute). From the post-questionnaire, all members were unanimous that the member #1 was a leader in the discussion, and the member #1 was found having maximal activity logs.

(2) Group C: This group spent about 38 minutes to make a decision but the conclusive restaurant was bookmarked earlier than group A. Interestingly, it appears that each group member of this group was equally voted as a leader.

(3) Group H: The period of time between the time point that the conclusive restaurant was initially bookmarked and the time point of decision making was shortest, while they spent the second shortest time for decision making. When compared to the other groups, this group engaged in the amounts of chatting and bookmarking per discussion time were compellingly larger. The member #2 was unanimously voted as a leader by the agreement of all members, according to the post-questionnaire.

4.4.1 Group A. Figure 3 illustrates the time-varying distributions of the activity logs of participants in group A.

It is apparent that whenever the amount of an activity X changed, that of any other activity Y changed in the opposite direction in the next interval. For instance, at the beginning, the members primarily engaged in chatting activity. Subsequently, the amounts of searching and viewing activities gradually increased while chatting activity decreased. As can be seen from the middle period to the end of the discussion, the members turned to involve more in chatting than searching or viewing activity. Nevertheless, the members barely searched for a restaurant at the end of the task but mainly engaged in chatting activity.

In this group, the eventually decided restaurant was firstly bookmarked at the 13th minute of the task. Later, the members also

[2]https://github.com/nkmrtty/WI2017-Dataset

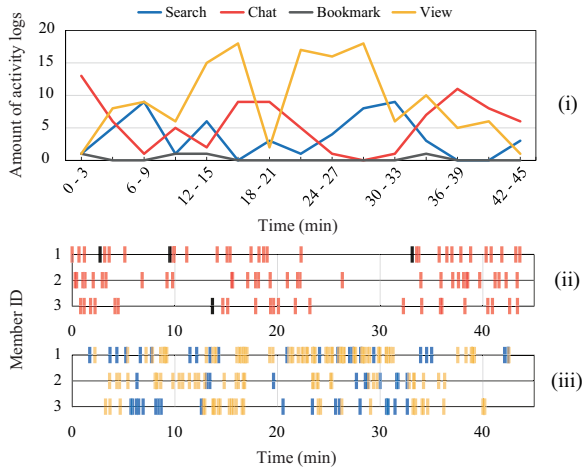

Figure 3: Time-varying distributions of the activity logs of group A. The blue, red, gray, and yellow line respectively refers to searching, chatting, bookmarking, and viewing activity. (i) shows total number of the activity logs of all group members, (ii) shows the time series plot of the activity logs shared with group members (chatting and bookmarking), and (iii) shows the time series plot of the activity logs invisible from group members (searching and viewing).

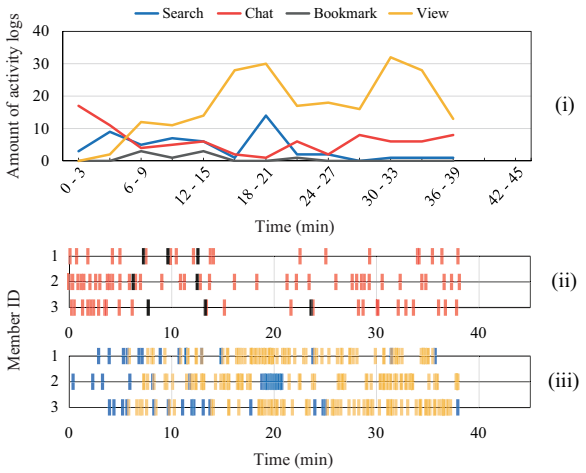

Figure 4: Time-varying distributions of activity logs of group C (see the caption of Figure 3 for the references of (i), (ii), and (iii)).

searched for and viewed another restaurant but bookmarked only one additional restaurant. Accordingly, it might be reasonable to suppose that the group was able to find a preferred restaurant at an early stage of discussion. Unlike other members, the member #1 still engaged in searching activity at the end. The evidence points to the possibility that the member #1, who was later voted as a leader, spent time in summing his opinion resulting in a long time spending from the point of time that the restaurant was firstly bookmarked to the decision-making point.

The member #2 and #3 reported in the post-questionnaire that the higher number of restaurants bookmarked by the member #1 and his active opinion expression on the restaurant genre were the reasons for voting him as a leader of the group discussion. Meanwhile, the member #1 gave the reason for voting for himself that he found himself checking opinions of the other members and confirming final consensus with the others. In addition, there was an evidence that the member #1 also bookmarked restaurants for three times which was higher than others (Table 2), and he was also the first person who started chatting and bookmarking restaurants (Figure 3) and was found very responsive person to the activities shared by the other members.

4.4.2 Group C. Figure 4 displays the time-varying distributions of the activity logs of members in group C, and the dynamics of activities were found similar to that of group A.

In this group, the conclusive restaurant was bookmarked even earlier than group A, but since then they also spent a comparable time (about 30 minutes) to group A to make a final decision. It can be observed that searching and viewing activities were noticeably more frequent than chatting activity. Especially, the trend of chatting was found decreasing in the first half of experiment. Despite an increasing trend, the number of chatting messages posted in the second half was found fewer than that in the first half, generally suggesting that this group needed a long time to start a specific discussion regarding the final selection from the candidate list of bookmarked restaurants.

Regarding a leading role, the main uniqueness of this group was the equal number of times (once) for which each group member was voted as a leader in the post-questionnaire. The member #1 gave the reason for voting the member #3 that the member #3 provided an opportunity to change the flow of the discussion. Similarly, The member #2 voted for the member #1 based on the evidence that the member #1 was the person who bookmarked the conclusive restaurant. Meanwhile, the eager actions of reviewing restaurants' details and sharing information with others were among the main reasons for the member #3 to vote for the member #2. Except for chatting activity, the amount of the activity logs were not found significantly different among the members.

4.4.3 Group H. Figure 5 shows time-varying distributions of the activity logs of members in group H. Albeit the dynamics of this group were found comparable to group A and C, this group spent notably shorter time since the conclusive restaurant was firstly bookmarked until the decision was finally made.

Unlike the other groups, the chatting frequency in this group was remarkably higher. As can be observed in Figure 5(i), the amount of chatting activity was found steadily larger than the other activities. While the searching and viewing activities were found less than the other groups, the members of this group were still able to reach a final satisfactory decision in merely 21 minutes. Regarding the leading role in the discussion, the member #2 was voted as a leader by all members including himself in the post-questionnaire, and his action of sharing numerous candidates of restaurants with appropriate consideration of others' preferences was the reason for the high voting score. It may be reasonable to imply that intensive discussion could lead to the possibility to reach a final decision in a relatively short time.

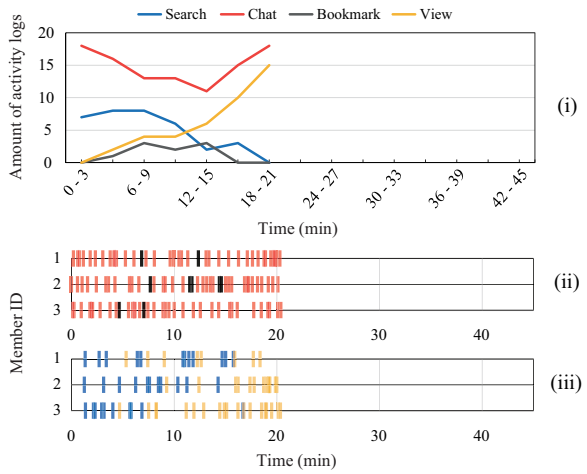

Figure 5: Time-varying distributions of activity logs of group H (see the caption of Figure 3 for the references of (i), (ii), and (iii)).

5 DISCUSSION

In this section, we firstly look at general implications of group decision making from three viewpoints mentioned in Section 1. Then, we discuss application designs based on our findings, followed by discussing on the limitations of this study and future works.

5.1 Group decision making

5.1.1 How group members carry out the group discussion with collaborative web search. Based on evidence in Section 4.4, we discuss on patterns of dynamics frequently found across all groups. At the beginning and the end of group discussions, the amount of chatting activities was relatively high. In particular, shortly after the beginning, group members started chatting rather than engaging in other activities. Later on, the amount of chatting activities decreased but eventually turned to be high again right before the end of the task. Secondly, group members gradually reduced searching activities and constantly kept viewing pages of restaurants until the end of the task. From this pattern, there might be qualitative behaviors through chatting activities immediately after the beginning and prior to end of group discussion. In order to clarify the behaviors, it is necessary to deliberately examine contents of chatting messages and the inter-participant interaction.

Another underlying reason for the evidence that some groups spent a long time until conclusions were reached was that the members of those groups repeated a similar set of actions over the course of time. Specifically, it could be observed from Figure 3 that group A might already find a very good candidate of restaurant around the 18th–21th minute. However, when further examining the contents of chatting messages, we found that the group members had strong belief to find a better candidate and started searching again instead of proceeding into the final decision making. In other words, the group was found having an iteration of individual activity (e.g. searching for restaurants) and collaborative activity (e.g. sharing preferences) resulting in a long time spending.

5.1.2 How dynamics of group decision making are associated with members' satisfactions with the conclusions. As shown in Section 4.3, almost all of the participants were satisfied with the conclusion of the group discussion. However, the time to reach the conclusion varied by groups. We further investigated the relationship between the period of time spent until a decision was made and the degree of satisfaction with conclusion across all groups by using Pearson's product-moment correlation analysis, and we found no significant correlations between them. Likewise, a significant association between the degree of satisfaction with any of activity logs was neither found. To gain more insight on the relationship between the satisfaction and activity logs, the information of general interaction with the experimental system might not suffice and further analyses on minute-level behaviors and on inter-participant interactions might be necessary and included into our future work.

5.1.3 What kind of role each member implicitly plays. We further examined the activities of the eventually-voted leaders in group decision making. As presented in Section 4.3, the post-questionnaire responses revealed that the voted leaders generally played dominant roles in summarizing opinions and discussion, suggesting the candidates of restaurants, and bookmarking a number of restaurants. For quantitative analysis, we examined the relationships between the voting score that a participant received and the intensity of each activity in with the participant engaged through Pearson's product-moment correlation analysis using all data of all participants. As a result, the intensities of chatting and bookmarking activities were found to be significantly associated with the voting scores (chat: $r = 0.424$, $p < 0.05$, bookmark: $r = 0.695$, $p < 0.001$). Generally speaking, the member who was likely to be voted as a leader tended to eagerly engage in activities that were shared with other members. Further investigation on the content of chatting messages and the information of the restaurants bookmarked by leaders would help identify the characteristics of leaders group decision making.

5.2 Application design

Here, we discuss a potential methodology to design intelligent interface systems to support group decision making based on dynamics of the group discussion.

With regards to Section 4.2 and 5.1, the length of time to make a group decision was not associated with the degree of satisfaction with the conclusion. Also, in a number of cases, group members were likely to spend a long time in deciding a conclusive restaurant albeit it was firstly bookmarked since the early stage of the group discussion. As explained in Section 5.1, the plausible underlying reason for a long discussion might be that the members shared their preferences at least once in the first half of the discussion but continued the discussion if an agreeable conclusion could not be made by then. The investigation on the dynamics in Section 4.4 suggests that such groups would either have unanimously voted leader when a group member kept searching for restaurants until the end, otherwise each group member would be equally voted as a leader. In contrast, a group whose members actively involved in the inter-participant interactions tended to spend a shorter time to reach a conclusion. Besides, similar patterns of activity transition

were found across all groups regardless of the length of group decision making.

When taking the concerns mentioned above into account, if group members need a long period of time to reach an agreement, the system can be designed to include an additional function allowing users to share their preferred searching options or the obtained results with other members rather than relying on chatting function. Further, recommendation on restaurants and searching options based on patterns extracted from the group discussion might be able to facilitate the searching activities.

Alternatively, an intelligent system can be developed specially to promote group discussion based on the status while performing a task. For instance, when there is no convergence in leader voting (e.g. the situation of group C in our experiment), the system itself might mediate the discussion by suggesting a certain preference information extracted from the searching options of group members. To obtain such information, the leader-alike system might raise questions regarding the reasons for bookmarking a restaurant. Nevertheless, one can argue that the intervention might impede the flow of group discussion at a wrong moment especially when group members have not searched sufficiently yet. Therefore, the questions *when* and *what* to interrupt the group discussion would be the ultimately important questions when implementing such system that can utilize the information of group dynamics.

One possible approach to addressing the *when* issue might be the estimation of current status and prediction of future status by utilizing historical information of status, activities, and inter-participant interaction in the group discussion, with the consideration on our finding of dynamics mentioned in Section 4.4 and 5.1. To address the *what* issue, a deep analysis of the chatting messages together with tracking temporal variation of group interest could be a good candidate. Our future works include a profound investigation into the feasibility of both approaches.

5.3 Limitation & Future work

In this paper, we investigated the dynamics of group decision making using activity logs recorded on our experimental system. However, as mentioned in Section 5.1 and 5.2, we have not examined the contents of chatting messages. The further analysis on the dynamics needs to be undertaken at the minute-level to enable the development of an intelligent system capable of tracking group interest and interacting with users in real time. Specifically, the purposes of posting the chatting messages, the motivation for reviewing preference of other members, the aim of expressing opinions, and latent emotional polarity inside chatting messages are to be clarified in the future work.

Additionally, we aim to investigate further on the other activities. For instance, viewing activity can be classified into two categories: viewing pages from search results, in which participants are likely to engage more in the first half of discussion, and viewing restaurant information picked from the bookmark list, which is likely to be undertaken in the second half. It is also encouraging to deeply investigate the consequence of a behavior on the following behaviors both within and across participants and also the causality. To exemplify, a restaurant that is bookmarked by a participant may perhaps influence another participant resulting in complying or changing search tactic. We expect that an intensive analysis of time-evolving behaviors of participants might have a further contribution to understanding the dynamics of group decision making.

6 SUMMARY

In this paper, we investigate dynamics of group decision making with collaborative web search aiming to reveal how activities of a group member could be influential on the activities of other members or on the degree of satisfaction with a conclusion. A set of experiments was conducted on 24 participants (3 members * 8 groups) with the task to search for a restaurant to go with other group members and make a decision. Considering the analysis of pre- and post-questionnaire, the primary results suggested that (1) at the beginning and the end of discussion, members of each group engaged in similar activities, (2) the period of time spent until reaching a conclusion was not significantly relevant to the satisfaction level with the conclusion, and (3) members who actively engaged in the activities that were visible for the other members were likely to be regarded as leaders for the group discussion. In the future work, we conduct a deep investigation to get more insights on the dynamics in higher temporal resolution. An intelligent system which is capable of supporting group decision making is aimed to be developed based on our findings, and further experiments are worthy to be conducted to assess the validity of the system.

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