

Cyber-Physical Hybrid Environment Using a Largescale Discussion System Enhances Audiences' Participation and Satisfaction in the Panel Discussion

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SUMMARY Performance based on multi-party discussion has been reported to be superior to that based on individuals. However, it is impossible that all participants simultaneously express opinions due to the time and space limitations in a large-scale discussion. In particular, only a few representative discussants and audiences can speak in conventional unidirectional discussions (e.g., panel discussion), although many participants gather for the discussion. To solve these problems, in this study, we proposed a cyber-physical discussion using “COLLAGREE,” which we developed for building consensus of large-scale online discussions. COLLAGREE is equipped with functions such as a facilitator, point ranking system, and display of discussion in tree structure. We focused on the relationship between satisfaction with the discussion and participants' desire to express opinions. We conducted the experiment in the panel discussion of an actual international conference. Participants who were audiences in the floor used COLLAGREE during the panel discussion. They responded to questionnaires after the experiment. The main findings are as follows: (1) Participation in online discussion was associated with the satisfaction of the participants; (2) Participants who desired to positively express opinions joined the cyber-space discussion; and (3) The satisfaction of participants who expressed opinions in the cyber-space discussion was higher than those of participants who expressed opinions in the real-space discussion and those who did not express opinions in both the cyber- and real-space discussions. Overall, active behaviors in the cyber-space discussion were associated with participants' satisfaction with the entire discussion, suggesting that cyberspace provided useful alternative opportunities to express opinions for audiences who used to listen to conventional unidirectional discussions passively. In addition, a complementary relationship exists between participation in the cyber-space and real-space discussions. These findings can serve to create a user-friendly discussion environment.
key words: large-scale cyber-physical discussion, COLLAGREE, satisfaction, attention, collective intelligence

1. Introduction

What is the possible application of online discussion systems? In the present study, we proposed an online discus-

sion system that provides a hybrid (i.e., cyber-physical) environment in which participants can discuss both in cyber and real spaces. This hybrid discussion system can collect potential opinions from participants who generally only listen to the opinions of a few representative discussants in a real-space discussion, and enhances the satisfaction of participants by facilitating their involvement in the discussions.

1.1 Large-Scale Discussion in Real Space

In decision making, consensus building, or providing ideas, performance based on multi-party discussion has been reported to be superior to that based on individuals [1], [2]. To enhance the quality of discussion outcomes, it is important for participants to exchange various opinions. Indeed, previous studies have shown that collective intelligence exceeds individual intelligence. For instance, an experiment using multiparty brainstorming or group matrix reasoning revealed that group performance predominated over individual performance [3]. In the intellectual field, studies conducted by research groups yielded higher impacts in terms of citation index than those conducted by a single researcher [4]. These findings suggest that the involvement of many participants enhances the quality of discussions.

However, as more participants gather in a real-space discussion, it becomes more difficult to arrange a discussion. For example, a large-scale real-space discussion prevents all participants from joining it. This problem can be caused by the fact that large-scale discussions contain many participants at the same time and place, which is a burden on participants. A vast amount of time is necessary if more participants have an opportunity to speak; simultaneous discussion by multiple individuals is also impossible. In addition, speaking in front of many audience members induces a psychological cost or pressure, e.g., getting nervous. Therefore, it is beneficial to eliminate these limitations of a large-scale real-space discussion.

It is also necessary to find a solution for collecting potential opinions of participants who passively listen to other participants' remarks throughout a discussion. Thus, we focused on a unidirectional large-scale real discussion in which a few representative discussants generally exchange opinions. For instance, in panel discussions and civic fo-

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rooms, panelists discuss issues while other attendees passively listen to the discussion, in spite of wanting to express their opinions about the issues. Given that participation in discussions enhances the satisfaction of participants [5], opportunities for participation in discussions can have positive effects on participants.

1.2 Large-Scale Online Discussion

Large-scale online discussion has been attracting attention recently. Web content such as online bulletin boards, blogs, or microblogs enable us to express opinions and discuss with each other through response or comment functions. Nonetheless, the functions of these sites do not focus on discussion of a specific topic, because users can post opinions regarding various (i.e., unlimited) topics and these sites are not specialized for discussion. Meanwhile, large-scale online systems that highlight a particular topic have been developed. For instance, Malone and Klein created an online discussion platform for reduction of greenhouse gases based on predictable discussion structures [6], [7]. This platform allowed complicated discussion to be systematic. They continued to use this platform to hold the Climate CoLab contest, which aimed to employ collective intelligence via online discussion [8]. As Malone et al.'s study showed, online discussion can be a solution for the problems of a large-scale discussion in the real world, because it does not require participants to attend a real-space discussion and reduces time constraint. Due to such benefits, online systems have been employed for discussion on social and political issues or urban planning [9].

1.3 Online Discussion System “COLLAGREE”

We proposed an online system “COLLAGREE” for building consensus of large-scale online discussion in our previous studies [10]–[15]. The remarkable features of COLLAGREE are as follows: (1) Facilitator: COLLAGREE contains a facilitator that plays the roles of progressing discussion from neutral perspectives and preventing flaming and groupthink [10], [11]. (2) Display of discussion in tree structure: to enhance understanding of the whole structure of discussion, COLLAGREE visualizes threads or responses to each post as a tree structure. Using some natural language processing technology, the discussion tree functioned like automatic summarization [12]. (3) Display of key words: key words featured during discussion through COLLAGREE [11]. (4) “Like” button: when participants agree with each posted comment, they can press the “like” button. The “like” button was arranged to allow easy expression of opinion [13]. (5) Discussion point: participants obtain points through posting their opinions [14], [15]. Points were given when participants posted, replied, or clicked “like.” (6) Discussion phase: The function of the discussion phase was to control the discussion process (i.e., divergence, convergence, and evaluation) [11].

COLLAGREE has been found to be apt for large-scale

virtual discussions [16], [17]. For instance, Imi et al. conducted a cyber discussion experiment on Nagoya Next Generation Total City Planning by collaborating with the Nagoya City Office in 2013, which included many citizens. In that experiment, the enrollment in the system was 264, number of posts was 1151, and views were 18466 [16]. Unlike conventional town meetings, this cyber discussion was able to involve many individuals from younger generations, whose participation in political or administrative activities are generally low. Indeed, over 1000 remarks are usually impossible in real discussions. Accordingly, COLLAGREE can collect many opinions from attendees unable to express opinions due to time and space limitations in conventional, real-space discussion. Therefore, COLLAGREE can collect opinions from the participants who have few opportunities to express their opinions in real-space discussion.

In addition, given that online conversation was perceived as making it easier to talk with other people than face-to-face conversation [18], online conversation enables low psychological cost, which represents participants' feelings of difficulty in expressing opinions [19], [20]. Hence, the threshold for expressing opinions in cyber-space (e.g., postings) can be lower than that in real-space [20]. Generally, when participants raise their hands and manifest their opinions in a large-scale real discussion, they need to pay high psychological costs because of pressure or anxiety. Some participants may give up speaking due to their shyness, although some participants would be happy to express their opinions in public. Meanwhile, participants are able to express their opinions in an online discussion by paying relatively low psychological costs [18]–[20]. In addition, previous studies suggested that anonymous posting of opinions, which is similar to the present study, could also lower psychological cost compared with speaking in the real-space discussion [18], [21]. Furthermore, cyber discussion can yield unique opinions without hindering the flow of the real-space discussion. In light of our previous finding that the contents of a cyber-physical discussion partially differed from that of a real one [22], such different perspectives from a real-space discussion can deepen a hybrid discussion.

1.4 Possibility of Cyber-Physical Discussion System

To solve the problems of large-scale discussions in the real world, in the present study, we created cyber-physical discussion settings using COLLAGREE and examined its efficacy. This hybrid (cyber-physical) environment aimed to enable active participation of many individuals. As mentioned earlier, in unidirectional discussions in real space, only limited participants such as panelists or representative discussants manifest their opinions, while many audiences in the floor passively listen to the discussion. Even in such situations, online discussion systems can provide chances for expressing their own opinions and reciprocal communication among other participants or panelists. Furthermore, COLLAGREE involving functions such as facilitator and discussion points can also enhance discussion quality [11].

Based on the findings that participation enhances satisfaction of participants [23], a hybrid discussion environment would enhance participants' satisfaction.

With regard to satisfaction of participants, we assumed that the satisfaction of participants who express opinions in the real-space discussion is inadequate, because remarks in the real-space discussion can be derived from questions or objections to discussion. Despite a high psychological cost, insufficiency of discussion can induce a strong desire to manifest opinions. Conversely, we hypothesized that higher satisfaction is obtained through the cyber-space discussion, because participants are able to express opinions with low psychological costs and freely discuss the topic from different perspectives than in the real-space discussion.

As preliminary research, we previously conducted an experiment with cyber-physical discussion at an international conference [22]. The results of that study suggested that: (1) participants continued to pay attention to cyber-physical discussion; (2) as mentioned above, on the basis of keyword extraction, although the contents of discussions in the real world and cyberspace overlapped with each other to a certain degree, several contents differed between both discussions; and (3) correlations existed between posting behavior and the length of comments. However, this previous study did not investigate the psychological indicators and individual data of participants. Therefore, some questions still remain. Do participants enjoy or are satisfied with the cyber-physical discussion? If so, who enjoys it, and what is associated with that enjoyment? The present study focused on these unclear issues.

1.5 Aims and Hypotheses

To overcome the temporal, spatial, and psychological obstacles of a large-scale discussion, we conducted an exploratory experiment by creating a new cyber-physical discussion system, by focusing on a large-scale cyber-physical discussion with a few panelists and floor participants. Through this attempt, we aimed to build a user-friendly discussion environment and contribute to collective decision making. In light of the advantages of hybrid environments and satisfaction depending on participation level, we examined the following hypotheses:

- H1 Participation in the cyber-space discussion enhances the degree of satisfaction of participants in the floor.
- H2 Participants who desire to express opinions behave actively in both real and cyber space.
- H3 Expression of opinions enhances satisfaction of participants in the cyber-space rather than real-space discussion.

2. Methods

We conducted the experiment at a panel discussion in an international conference.

2.1 Participants

We selected nineteen participants in the panel discussion who had browsed COLLAGREE at least once and responded to questionnaires after the discussion. We eliminated the data of the posts by experimenters. All of the participants were floor audience members. Ten participants were from Japan, which was the highest number of participants in this discussion. Other participants were from France, Australia, and so on.

2.2 Instrument

We recorded the participants in the floor during the panel discussion using three video cameras above the screen of the stage, which provided a complete view of participants on the floor. For the analysis of participants' gaze, we used the footage from two of these cameras.

Participants logged in COLLAGREE via their own personal computers or smart phones to attend the virtual discussion. The user interface of COLLAGREE is shown in Fig. 1. We used the following functions of COLLAGREE, which we described in detail in Sect. 1.3: facilitator, display of discussion in tree structure, display of key words, "like" button, and discussion point. Because it was not necessary to converge opinions in this panel discussion, with respect to the discussion phase, only the divergence phase was used in this session.

2.3 Procedure

We conducted the experiment in the panel discussion (Who will take responsibility when AI make errors and how? [Can we make AI to be ethical or to have ethical reasoning?]) in IEEE International Conference on Agents (IEEE ICA 2016) from 13:00–14:30 p.m. on 28 November 2016. In this topic, it appears to be easy to discuss and control influences of individual differences between participants derived from the level of technical expertise. The session was conducted in English.

Before the panel discussion, we explained how to use COLLAGREE and provided informed consent. We asked participants to respond to the questionnaires before and after the panel discussion. We provided participants with IDs (e.g., "ICA-001") and passwords that allowed them to log into COLLAGREE, which enabled anonymous discussion. Before the experiment, we assigned IDs, passwords, and questionnaires to each seat. This setting allowed us to connect the ID of each seat with the recorded behavior of each participant while protecting anonymity.

2.4 Analysis

For the indicator of behavior in the online discussion, we analyzed the following items from participants' logs on COLLAGREE during the panel discussion: the number of views,

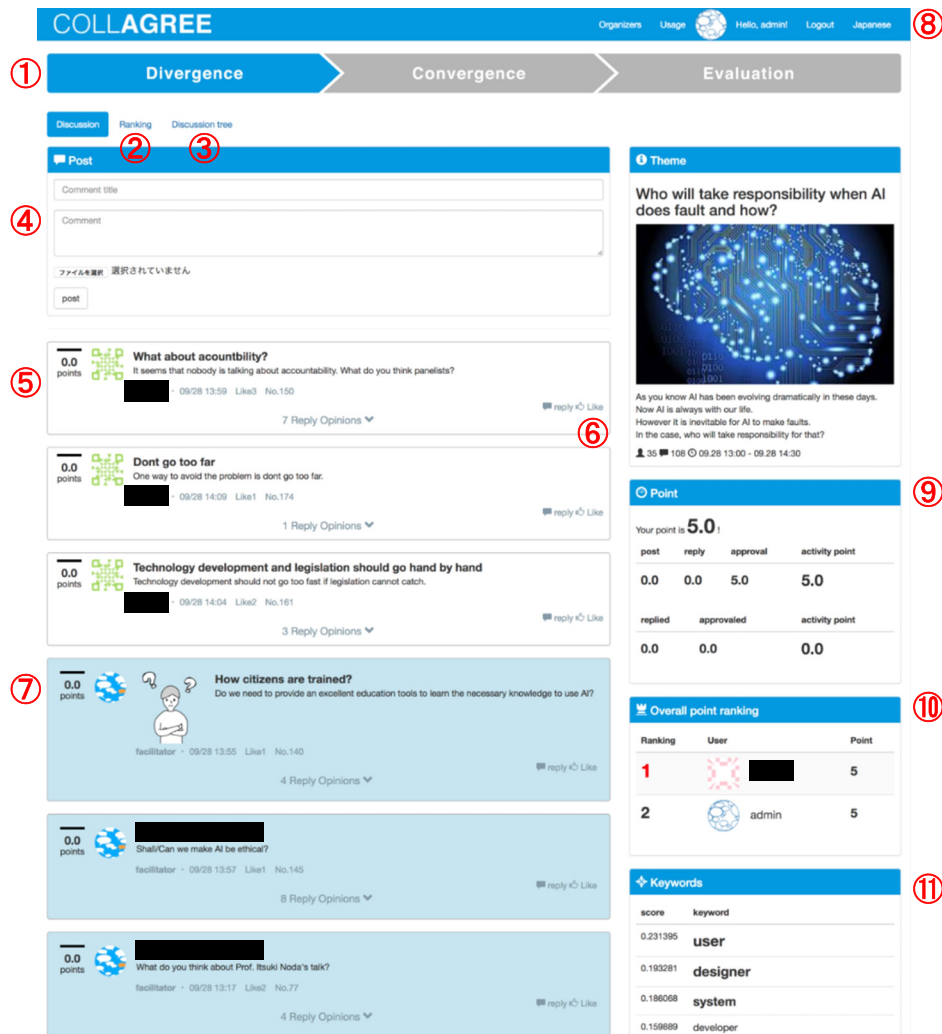


Fig. 1 User interface of COLLAGREE. We masked several parts using black squares where panelists' names or ID were written. Each index represents: 1. Discussion phase; 2. User ranking that includes some type of ranking data such as number of posts; 3. Discussion tree visually depicted a tree-shaped structure of the discussion; 4. Space for posting; 5. User-posted comment, which can include replies to the post; 6. "Like" button; 7. Facilitator-posted comment; 8. Menu bar that includes usage instructions, logout button, and so on; 9. Cumulative points earned through use; 10. Point ranking; 11. Key word ranking.

posts, words included in posts, characters, and "likes."

Although the questionnaire included other items for the purpose of a different study, we analyzed the following two items: "Did you enjoy discussion in the session?" (five-point scale), "Did you have any opinion or comment to express in the session?" (Yes/No). As the indicator for degree of satisfaction with the session, we used the ratings of the item "Did you enjoy discussion in the session?" The main reasons were as follows: 1. previous studies have suggested that positive affect (i.e., enjoyment or pleasure) was closely tied to satisfaction [24], [25], and 2. the present study included questionnaire items for other study. Thus, to avoid participants' confusing this question with another question for other study that asked about the degree of satisfaction with the results of the discussion, we defined the rating of enjoyment as satisfaction with the whole discussion.

In addition, participants could rate enjoyment of discussion rather than enjoyment of using this online system, because this question was involved in the questionnaire items for the panel discussion but separated from the questionnaire items of usability of this system for another study.

As an indicator of participants' attention toward the real discussion, we measured the duration of participants' gaze toward the stage or speaker, by using the recorded footage that monitored the floor, because gaze has been observed as an indicator of visual attention [26]. The measuring procedures were as follows. First, we separated the footage that monitored the floor during the panel discussion per 30 seconds and excerpted them. Second, three experimenters determined whether each participant directed gaze toward the stage or speaker in the recorded footage. When opinions of the three experimenters differed, they decided

through consultations.

3. Results and Discussions

3.1 Attention Toward the Real Discussion and Online Behavior

Figure 2 shows the mean ratio of gaze toward the real-space discussion and the total views of COLLAGREE per three minutes. The correlation coefficient between gaze toward the real discussion and the number of participants who browsed COLLAGREE was -0.62 ($p = 0.003$). This result revealed that when attention toward the real-space discussion was higher, the attention toward the online discussion was lower, and vice versa.

This result also clarified a complementary relationship between attention toward the real and online discussions on COLLAGREE. Furthermore, this result suggests that both the online and real-space discussions attracted attention from participants because when attention toward the real-space discussion decreased, attention toward the online discussion increased. Consequently, we found complementary participation among participants in both cyber-space and real-space discussions. This result supports previous studies [22].

We conducted principal component analysis employing each indicator of each participant's behavior on COLLAGREE throughout the session (e.g., each participant's total number of postings in the session). The result showed two factors (Table 1). We assumed that factor I indicates the active use of COLLAGREE in terms of the number of posts and the number of words in the posts, while Factor II indicates the relatively passive use of COLLAGREE in terms of the number of views or "likes." These results suggest that two types of use of COLLAGREE exist: active (i.e., Factor I) and passive (i.e., Factor II). Hereinafter, we analyzed active and passive behavior in the cyber-space discussion using the factor score of each factor as the indicators.

3.2 Response to the Cyber-Physical Discussion

We regarded the ratings of the questionnaire item "Did you

enjoy discussion in the session?" as the degree of satisfaction. We calculated a correlation coefficient between the ratings and participants' behavior on COLLAGREE (Table 2). With respect to calculation of correlation coefficients and the next regression analysis, we used each participant's ratings of satisfaction, factor score of principal component analysis, and gazing. The result showed a significant positive correlation between the degree of satisfaction and the active behavior on COLLAGREE, and a negative correlation between the degree of satisfaction and attention toward the real-space discussion.

We conducted a multiple regression analysis using the degree of satisfaction as the dependent variable and behavior on cyber-physical discussion as the independent variable (Table 3). The coefficient of determination (adjusted R^2) was 0.40. Therefore, this model showed good fitness. The regression coefficient of β of Factor I was marginally significant. This result suggests that active use of COLLAGREE marginally significantly influenced participants' satisfaction with the session. With respect to passive use of COLLAGREE, the regression coefficient was also positive. In addition, attention toward the real-space discussion was negatively correlated the participants' satisfaction with the session. Accordingly, the satisfaction of participants can be associated with attention toward the cyber-space discussion

Table 1 Results of factor analysis of indices of COLLAGREE use

	Factor I	Factor II
Number of posts	.95	-.13
Number of words	.92	-.22
Number of characters	.91	-.23
Number of threads	.81	-.28
Number of views	.42	.85
Number of likes	.49	.82
Percentage of variance	60.9	26.6

Table 2 Correlation coefficients between the degree of satisfaction and behavior on cyber-physical discussion

	Satisfaction
Attention toward real discussion	-.53*
Factor I	.47*
Factor II	.45

** $p < .01$, * $p < .05$

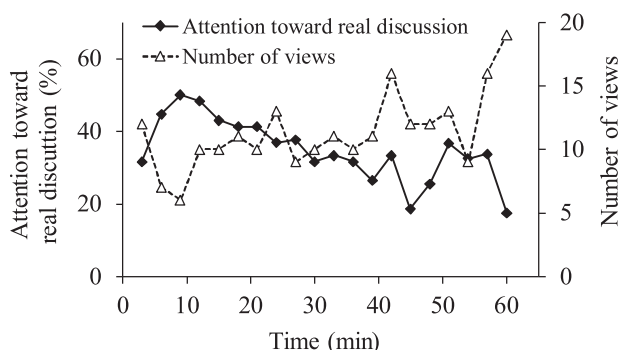


Fig. 2 Time lapse of attention toward the real-space discussion and total number of views

Table 3 Results of linear regression analysis with degree of satisfaction as the dependent variable and participants' behavior in the cyber-physical discussion as the independent variable.

	<i>B</i>	<i>SE</i>	β	<i>t</i>	<i>p</i>
Attention toward real space	-1.26	0.84	-0.31	-1.49	0.16
Factor I	0.40	0.19	0.39	2.08	0.06
Factor II	0.34	0.20	0.34	1.69	0.11
Const.	3.96	0.35		11.48	<0.01

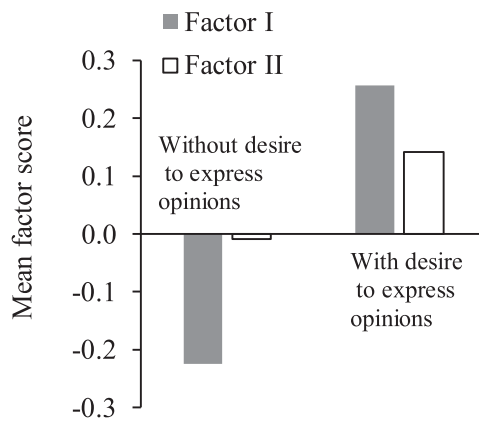


Fig. 3 Mean factor score of Factors I and II of participants with or without desire to express opinions

rather than attention toward the real-space discussion.

These results suggested an association between the participants' satisfaction with panel discussion and participation in virtual discussion. Thus, H1 was supported.

3.3 Desire to Express Opinions and Behavior on Virtual Discussion

We regarded responses to the item “Did you have any opinions or comments to express in the session?” as the desire to express opinions. Ten participants responded that they wanted to express opinions, whereas seven participants did not. Two participants were eliminated, because they did not respond to this item. Regarding participants with or without desire to express opinions, Fig. 3 and Fig. 4 show the mean factor score of Factors I and II (Fig. 3) and attention toward the real discussion (Fig. 4).

With respect to the factor scores of Factors I and II of participants' behaviors on COLLAGREE, the ratings of participants with desire to express opinions were higher than those with no desire. Furthermore, participants who had desire to express opinions showed lower level of attention toward the real discussion. However, the result of a t-test showed no significant difference between the indicators of desire and non-desire to express opinions [$t(15) = 0.934$, *ns*, for Factor I; $t(15) = 0.290$, *ns*, for Factor II; $t(15) = 1.056$, *ns*, for attention toward the real discussion]. The results sug-

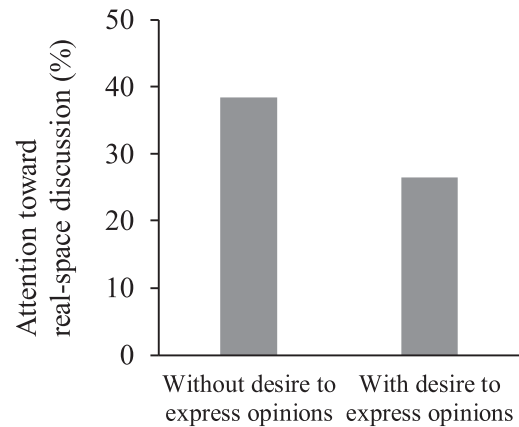


Fig. 4 Mean attention toward the real discussion of participants with or without the desire to express opinions

Table 4 Three types of participant behavior in the cyber-physical discussion.

	Attention toward real discussion (%)	Ratio of viewing COLLAGREE (times/30 sec)	Ratings of enjoyment
Express opinions in real space	46.2	0.06	3.0
Only posting	28.4	0.15	4.5
Only viewing	35.2	0.09	3.1

gested that participants who had desire to express opinions appeared to be active on COLLAGREE, whereas they appeared to pay less attention toward the real discussion; however, no statistical significance was obtained. These results suggested that participants who wanted to express opinions in the panel discussion were inclined to show active behavior in the cyber-space discussion.

Thus, H2 is supported to some degree. Participants who had desire to express opinions were predominantly involved in the cyber-space discussion. The present result showed that participants' satisfaction in the cyber-physical discussion increased by mainly using the cyber discussion space.

We compared the participants who made remarks in the real discussion (they also posted in the cyber discussion), participants who posted only in the cyber discussion, and participants who only browsed COLLAGREE (Table 4); the numbers for which were 3, 6, and 10, respectively. Variables for the comparisons were attention toward the real-space discussion during the session, views per 30 seconds in the cyber-space discussion (i.e., COLLAGREE), and the average ratings of enjoyment. As noted in Sect. 2.1, all participants browsed COLLAGREE at least once.

First, the participants who spoke in the real-space discussion tended to pay attention to the real-space discussion. Conversely, their views on COLLAGREE (i.e., paying at-

tention to the cyber-space discussion) were relatively lower than those of other groups. They also had low satisfaction. Second, the participants who said nothing in the real discussion but posted in the cyber discussion were inclined to pay more and less attention to the cyber and real discussions respectively; these participants had the highest satisfaction. Finally, the participants who neither spoke in the real discussion nor posted in the cyber discussion did not pay attention to the real and cyber discussions; these participants had low satisfaction.

Accordingly, participation in the cyber discussion affected satisfaction of participants more significantly than in the real discussion. Although previous studies showed that participation in a real-space discussion was found to enhance participants' satisfaction [5], [23], the present results suggest that participation in a cyber discussion rather than real discussion enhances the satisfaction of participants. In addition, posting opinions in a cyber discussion can require less psychological costs. In summary, there were many participants who did not speak in the real discussion but posted in the cyber discussion, which contributed to the collection of numerous opinions. Thus, H3 was supported.

4. Conclusion

The present study investigated participants' behavior and psychological responses in a hybrid (cyber-physical) discussion environment. The results suggested that participation in an online discussion enhances participants' satisfaction compared with a real panel discussion. The main results were as follows: (1) participation in online discussion was associated with the satisfaction of participants. (2) Participants who had desire to express opinions positively joined in the cyber discussion space. (3) The satisfaction of participants who expressed opinions in the cyber-space discussion was higher than those of participants who expressed opinions in the real-space discussion and those who did not express opinions in both the cyber- and real-space discussions. Hence, a hybrid cyber-physical discussion environment can serve to enhance participants' satisfaction with discussion, even if they do not participate in a real-space discussion. This result accords with the findings that participation facilitates satisfaction [5], [23]. In addition, the number of participants who posted opinions via the cyber discussion was significantly higher, whereas the number of participants who remarked in the real discussion was limited. Overall, because of the cyber-physical hybrid environment, our large-scale discussion system contributes to accumulating more opinions even in conventional discussions comprising a few representative discussants and audiences in the floor, which contribute to development of collective intelligence [1]–[4]. Furthermore, our findings of satisfaction of participants serve for user-friendly discussion environment.

In future studies, we should examine individual differences in a hybrid (cyber-physical) discussion environment. For example, objective English skills of each par-

ticipant (e.g., native English speaker or not) may influence psychological cost when expressing opinions. Technical knowledge may also affect how participants engage in a discussion—namely, how they use the real and cyber spaces. Furthermore, it is possible to explore individuals' aptitude for real and cyber spaces depending on their degree of satisfaction with degree of discussion in each space.

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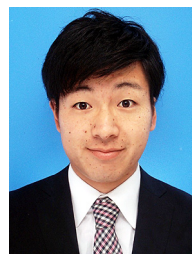


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