対話エージェントを用いた集団による協同問題解決の支援に関する研究

How do Conversational Agents with " Different Perspective " Assist Collaborative Problem-solving?

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Abstract

The presented study explores how different perspective in a group based problem-solving task contributes to the emergence of a new and creative perspective. Effects of the following two factors were tested through a computer simulated set-up: (1) consistent opinions from different perspectives and (2) consistent meta-cognitive suggestions. In an experiment, these factors were investigated using conversational agents. A situation was reconstructed, where problem-solving situation where problem solvers collaborate with each other via a text-based chat system. Results obtained in the experiment suggest that a synergy of the two factors can lead to the emergence of ideas during collaboration. The paper also discusses implications of the study for designing collaborative environments with conversational agents.

Keywords — Collaborative Problem Solving, Different Perspectives, Conversational Agent

1. Introduction

The ever-evolving information and communication technology has brought us to a stage where people can collaborate through dynamic and complex networks (i.e. the World-Wide Web). It has also made it possible to use conversational agents which can facilitate collaborative problem solving. There has been however few empirical studies investigating factors to foster the performance of collaborative problem solving. In the following, it is discussed how effective collaborative environments could be created by conversational agents.

1.1 Opinion from a different perspective: The consistent perspective factor

One of the negative effects in collaborative groupwork is social influence. Social influence forces people to adapt one's perspective to the other. This kind of adoption often occurs in the process of decision making in a group. Social influence tends to ignore minority views, favoring a certain perspective, whether that latter perspective is ideal or not. A certain perspective is also thought to be favored when people encounter only partially defined situations. When problems solvers confront unfamiliar or uncertain problems they are thus easily influenced by perspectives dominant in the group. Such situations are similar to those discussed in the 'Paradigm Theory' by Thomas Kuhn (1962)[4].

When people are fixated and biased in favor of a typical perspective within a group, one of the key factors to make a breakthrough is to take into consideration a dissenting opinion from a member that takes a different perspective. In psychology this type of social influence is called the "minority influence" and it is affected by several factors, such as size of the group, consistency of the view by the minority group, situation, etc. Past studies have shown that the influence of a minority perspective is a desirable condition for increasing the diversity of views, prompting reconsideration, processing information and making a decision [7], [8].

In this study, the idea of minority influence is expanded to collaborative problem solving. The term ' minority ' is used to resemble a member with different perspectives in collaborative problem solving. This minority has an important perspective to improve problem solving performance inside the group.

It is hypothesized that opinions from minorities can be effective when different perspectives are presented consistently. This is scrutinized throughout an experiment assumption further called the “ consistent perspective factor ”.

1.2 Meta-suggestions: The meta-suggestion factor

As mentioned above, problem solving in a group often becomes difficult when social influence is present. Nevertheless, a different perspective can make an important contribution to the problem solving. A question to be further investigated is, then, what kind of communication would constitute an effective strategy for collaborative problem solving.

In Cognitive Science, many studies have investigated what contributes most to collaborative problem solving. It has been found that different perspectives brought into a group promote effective interaction in collaborative problem solving [6], [10], [2]. Miyake (1986) and Okada & Simon (1997) reported that asking reflective questions to conversational partners is a useful interaction strategy for gaining a deeper understanding about the problem. Conversations, such as asking for explanations and providing abstract suggestions, are assumed to stimulate reflective thoughts and meta cognition. Shirouzu, Miyake, & Masukawa (2002) suggested that taking different roles is an effective way to reconstruct the problem solvers external representation. The authors also showed that this activity is effective for reconstructing the involved individuals ’concepts and promoting creative thoughts.

All these studies also found that meta suggestions are useful in settings, such as collaborative problem solving in small groups. It is presumed that meta suggestions lead to promoting new perspectives when they are delivered by minorities. The presented study focuses on suggestions, such as“ asking explanations ”, “ communication on alternative ideas ”, “ confirmations of ideas ”, and ”giving suggestions about procedures of problem solving ”. Relevant conversations are investigated throughout an experiment where this “ suggestion factor ” was artificially introduced.

1.3 Aim of the study

In this study, effects of consistent different perspectives and suggestions were investigated during collaborative problem solving, when solvers are biased to a particular view point. The following three issues are investigated:

1. Do different perspectives emerge when a member consistently takes different perspectives?
2. Do different perspectives emerge when minorities ask partners to provide meta suggestions, such as explanations and suggestions?
3. Does the synergy of the above two factors above enhance problem solving performance?

To examine these situations, an experiment is conducted using conversational agents which play the role of human partners. Based on results obtaining, it is discussed how conversational agents would support collaborative problem solving.

2. EXPERIMENT OF DESIGN

In this study, an experimental design originally proposed in Hayashi et al. (2006) was used. In this experiment, two participants are engaged in a rule discovery task, but are provided with different perspectives.

図 1 Example of a figure with a complimentary back ground.

2.1 Controlling the participants ’ perspective

In the experiment, a combination of blocks was shown on different backgrounds to derive Gestalt effects [3] and thus control the participants ’ perspective. Figure 1 is a well-known illustration which may look like a vase or two faces, depending on where the visual focus is. When the focus is on the white color, a vase pops out as the figure and the black part becomes its background. On the other hand, when the focus is on the black color, two faces pop out while the white part becomes the background.

Following this idea, several sets of random patterns consisting of squares on a 6 x 6 grid base were generated, each colored black or white (see Figure 2.

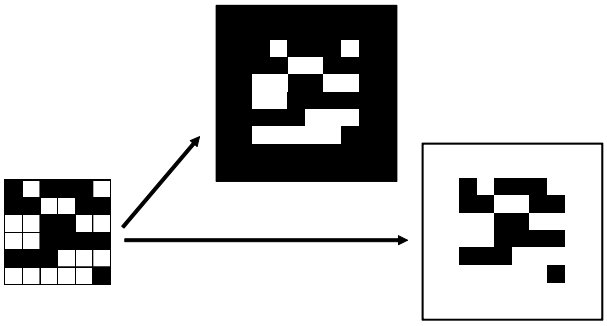

図 2 Example of stimuli.

Each set has several components, each of which consists of a single or a few combined squares forming an " object ". In one example shown in Figure 1, there is a total of ten objects comprising four black objects and six white objects. They were displayed on either black or white background. Participants acquire a distinct perspective when focusing on objects whose color is different from the background color. That is, when they focus on white objects, the white objects become figure and black objects become the background and vice versa. When participants focus on the white objects in Figure 2, for example, six objects pop out and form the figure. When the focus is on the four black objects, these latter objects are seen as the figure.

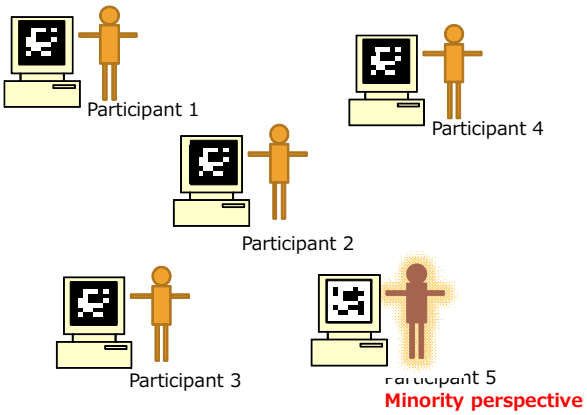

図 3 Example of experimental situation.

In the experiment, five participants are engaged in a collaborative problem-solving work through computer terminals connected via a local network. Figure 3 illustrates a setting where different perspectives exist, as they are induced by changing the background color of the outer frame. In this setting, the minority member presumably has a different perspective due to his/her focus on black objects.

Before starting the task, a squared outer was shown on each participant 's display for one second; a stimulus picture was then presented inside this frame. The frame and the stimulus were presented in pairs in succession (see Figure 4).

The number of white and black objects was controlled with the total number of the objects varied between six and twelve (see Table 1). As shown in Table 1, the sequential patterns of the sums of black objects and white objects are repeated (i.e. 6, 8, 10 / 6, 8, 10). When participants focus on only one of the two colors, however, they cannot find this target rule. To discover the sequential regularity of the sum, the problem solvers have to look at the objects from two different perspectives by focusing on two different colors. The important point to solve this problem is that the problem solvers need to realize the existence of an alternative set of hidden objects (shown in black). Minority participants (agents) are provided with a set of objects manipulatively, so that they can easily focus on the hidden objects and communicate the rest of the majority participants the information that would lead to the discovery of the target rules.

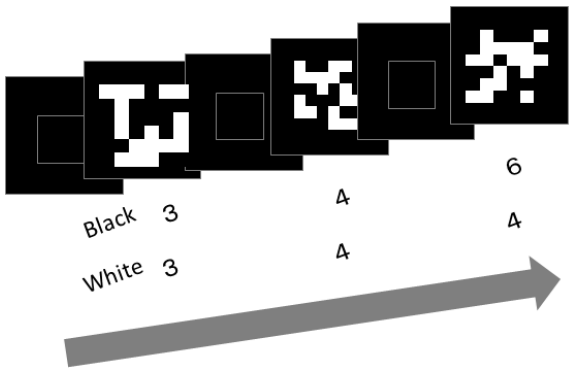

図 4 Series of presented stimuli.

表 1 Example of sequences of the presented objects.

White (Majority)	4	6	4	7	2	4	6	5	3
Black (Minority)	2	2	6	5	4	4	4	7	3
Sum of Black and white	6	8	10	12	6	8	10	12	6

Figure 5 illustrates the interface of a text-based information exchange where the participants can type in and receive messages to discuss the target rule. The participants were told that the stimuli presented inside the frame are identical for all other participants. Buttons to change objects, send messages, and to terminate the experiment were placed at the bottom of the screen. In the experiment, the participants were

allowed to write only one sentence with a maximum of 30 characters per pair and were asked to finish the task within 30 minutes.

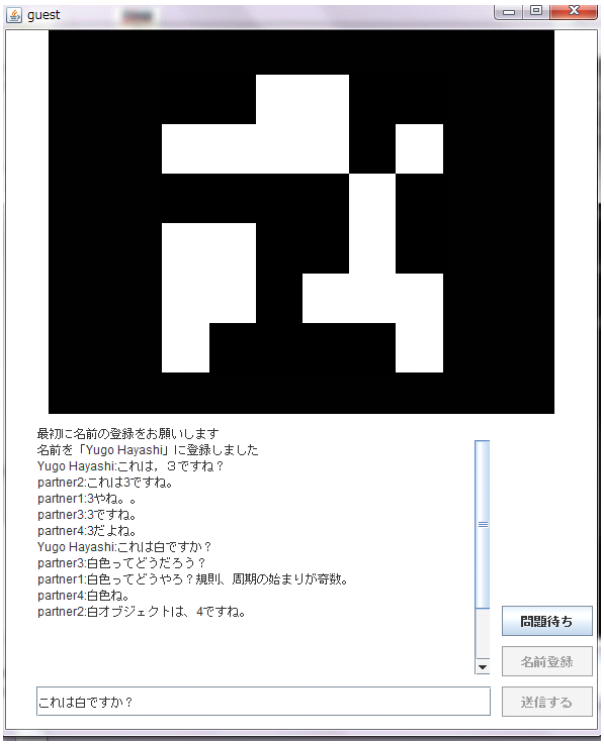

図 5 Example of the interface.

2.2 Conversational agents and the experimental system

The system used in the experiment was implemented in Java (see Figure6). Four program modules are automatically activated: (1) Server, (2) Client, (3) Agent, and (4) Problem Generator. The GUI is presented in the Client program. The four programs were developed to work in a local area network environment. Multi-threads are used for the Server program to process all the messages simultaneously. When messages are sent to the Server, they distributed to all the Clients (Agents). The Problem Generator generates the sequence, as shown in Table 1. This module also provides important information about the objects presented on the GUI as well as about the sequence of the stimuli. Agents use this information to generate conversations.

A simple conversational computer agent used in this study is a typical rule-based system. It has an ability to meaningfully respond to sentences input by the user, based on pre-defined rules. The agent has

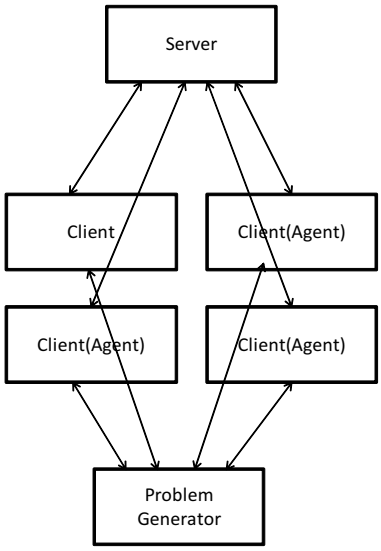

図 6 Example of the interface.

three main modules: (1) Semantic Analyzer, (2) Generator, and (3) Motion Handler (see Figure 8).

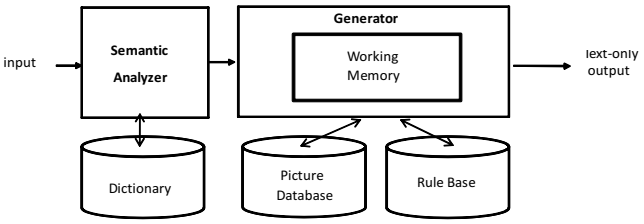

図 7 Structure of the agent.

The Semantic Analyzer extracts keywords from the input messages and detects keywords relevant to the task. Keywords collected from a previous study were used to build the Dictionary containing important keywords originally the task[2]. The Working Memory is created by the Generator, and it basically has two states associated with: (a) Presented objects (Picture Database), and (b) Detected key words (Semantic Analyzer). Various types of argument statements are stored in the Rule Base in the 'if-then' format. Definitions from the Working Memory are sent to the Rule Base to search for matching statements. When there are several overlapping statements, a simple conflict-resolution strategy is utilized. As the matching process ends, the selected sentences are sent to the Generator, definitions in the Working Memory are updated, and the output is displayed.

An experimental situation was modeled by using these conversational agents to play the role of human partners. As shown in Figure 9, participants are instructed that they are interacting with real people,

but they are actually engaged in the task alone.

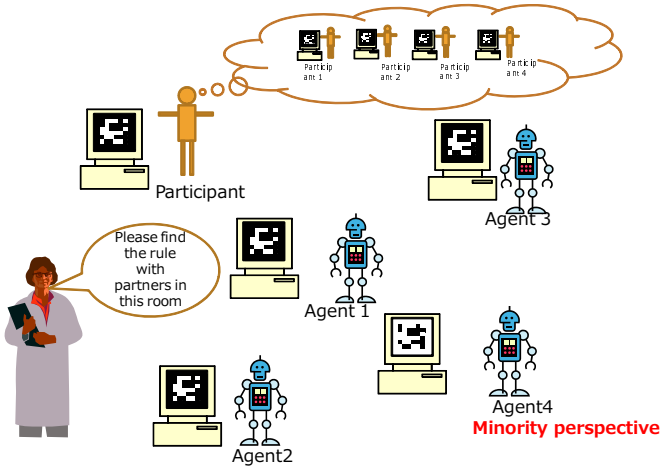

図 8 Experimental set-up.

3. EXPERIMENT DESIGN

3.1 Controlled factors

The experiment has a 2 x 2 between-subjects factorial design. The two factors are: (1) consistent opinions from different viewpoints, and (2) consistent suggestions.

The first, ‘ consistent perspective factor ’ is controlled by observing whether the minority consistently communicated on a different perspective (the background) or they did not. The second, ‘ suggestion factor ’ was controlled by observing whether the minority gave meta-suggestions, such as explanations about the participant perspectives or they did not. The minority provided meta suggestions such as (1) asking for explanations, (2) communicating on alternative ideas, (3) conformation, and (4) suggestions of how to solve the task.

In the Consistent perspective/Suggestion condition, the minority agent would chat about consistent different perspectives and meta suggestions. In the Consistent perspective/No suggestion condition, the minority agent would chat about consistent different perspectives but not about meta suggestions. In the No consistent perspective/Suggestion condition, the minority agent would not chat about consistent different perspectives but would chat about meta suggestions. In the No consistent perspective/No suggestion condition minorities would not chat about any of the two conversations. See tables 2 and 3 for conversation examples on Consistent perspective/No suggestion condition and No consistent perspective/ Suggestion condition.

表 2 Example of conversations in Consistent perspective / No suggestion condition.

	participant	Majority agent	Majority agent	Majority agent	Minority agent
Trial 1	I think this are three.	Three objects	Yes, three	I think three	I can see the black objects
Trial 2	I think this are four.	Yea, four objects	I think four	Four objects	Aren't there 4 black ones?
Trial 3	I think this are five white	White and five	Definitely white and five	Five white objects	Black objects are 6!!

表 3 Example of conversations in Consistent perspective / Suggestion condition.

	participant	Majority agent	Majority agent	Majority agent	Minority agent
Trial 1	I think this are three.	Three objects	Yes, three	I think three	What about looking at the task from a different view?
Trial 2	I think this are four.	Yea, four objects	I think four	Four objects	Maybe we should stop here and look if our hypotheses are correct.
Trial 3	I think this are five white	White and five	Definitely white and five	Five white objects	Why do you think your counting is correct?

3.2 Participants

120 undergraduate students participated in the experiment (males = 42, females = 78, average age = 20.4 years). All participants were randomly assigned to each condition (30 participants per condition). The participants, who did not follow the instructions, did not answer the final questions, or felt suspicious about their partners were excluded from data. Table 4 shows the number of participants who were finally assigned to each condition.

表 4 Number of participants included into analysis.

	Consistent perspective condition	No consistent perspective condition
Suggestion condition	24	21
No suggestion	21	21

The experiment was conducted in a computer room containing a maximum of 60 people. The computers were all connected to the local area network. The program of the experiment was installed on a USB memory stick, and was handed over to the partici-

pants. All conversations were recorded as logs.

3.3 Dependant variables

Two sets of data were used to evaluate collaborative problem solving on two levels: Problem solving performance and the perspective changing process.

After the task, participants were asked to answer the target rule using an answer sheet. The answer sheets were analyzed for estimating the‘ problem solving performance ’. When the answer was related to the black and white objects, they were evaluated as ‘ correct ’, e.g. the sum of the black and white objects rotates 6,8,10, the difference between the black and white objects ranges from 0 to 2, etc. On the other hand, when answers did not include such information, they were evaluated as ‘ incorrect ’.

The participant ’s conversation data was analyzed for estimating the ‘ perspective changing processes ’ during the problem solving. When the conversation included keywords about the background color, it was classified as‘ perspective change ’, e.g. “ I was counting only the white objects, but maybe the black objects have to do something with the target rule··· ”.On the other hand, when conversations did not include such information, they were evaluated as ‘ no perspective change ’.

4. RESULTS

4.1 Problem Solving Performance

Figure 9 shows results of the estimation of the problem solving performance. The vertical axis represents the ratio of the problem solving performance, and the horizontal axis represents the experimental condition. The studies focus is to investigate how the two factors, consistent opinions from different viewpoints and consistent meta-cognitive suggestions, influence the performance. Therefore, an ANOVA was conducted using the chi-square distribution, based on the arcsine transformation method. This method enables detecting both the main effects and the interaction of the two experimental factors.

The analysis was thus performed by a 2 x 2 ANOVA with the factor of Consistent perspective (Consistent perspective condition vs. No consistent perspective condition) and the factor of Suggestion (Suggestion condition vs. No suggestion condition) as a between-subject factor.

There was detected an interaction between the two factors ($\chi^2(1) = 5.21, p < .05$). An analysis of the simple main effect was conducted on each level of the consistent perspective factor. In the No consistent perspective condition, the ratio of problem solving performance in the Suggestion condition was higher than the No suggestion condition($\chi^2(1) = 6.51, p < .01$). However, there were no differences detected between the two factors in the Consistent perspective condition($\chi^2 1) = 0.46, p = .50$).

Next, an analysis of the simple main effect was conducted on each level of the suggestion factor. In the No suggestion condition, the ratio of problem solving performance in the Consistent perspective condition was higher than in the No consistent perspective condition($\chi^2(1) = 25.14, p < .01$). T there were detected only marginal differences between the two factors in the Suggestion condition($\chi^2(1) = 3.19, p = .07$). There was detected the main effect in the Consistent perspective factor but there were detected only marginal differences in the Suggestion factor($\chi^2(1) = 23.13, p < .01; X2(1) = 1.76, p = .08$).

The results obtained have several implications. First, the problem solving performance in the Consistent perspective/No suggestion condition and No consistent perspective/Suggestion condition was better than in the No consistent perspective/No perspective condition. This indicates that providing different perspectives by minorities is an effective strategy for improving the problem solving performance.

The performance in the Consistent perspective/Suggestion condition was not superior to neither No consistent perspective /Suggestion condition nor Consistent perspective /No suggestion condition. The statistical results show that there was only a marginal difference between these two conditions. This indicates that the synergies of the two types of perspectives were not superior as was hypothesized for this level.

4.2 Perspective change process

Figure 10 shows results of the estimation of the performance of problem solving. The vertical axis represents the ratio of the perspective change process, and the horizontal axis represents the experimental condition. An ANOVA was conducted using the chi-square distribution, based on the arcsine transformation method.

The analysis was thus performed by a 2 x 2 ANOVA with the factor of consistent perspective (consistent perspective condition vs. no consistent perspective condition) and the factor of suggestion (suggestion condition vs. no suggestion condition) as a between-subject factor.

There was detected an interaction between the two factors ($\chi^2(1) = 3.67, p < .05$). An analysis of the simple main effect was done on each level of the consistent perspective factor. In the no consistent perspective condition, the ratio of the perspective change process in the suggestion condition was higher than in the no suggestion condition($\chi^2(1) = 6.51, p < .01$). There were no differences found between the two factors in the Consistent perspective condition($\chi^2(1) = 0.02, p = .88$). These results are consistent with the problem solving performance discussed in the previous section.

Next, an analysis of the simple main effect was conducted on each level of the suggestion factor. Both in the suggestion and no suggestion conditions, the ratio of the perspective change process in the consistent perspective condition was found to be higher than in the no consistent perspective condition($\chi^2(1) = 6.86, p < .01; \chi^2(1) = 28.38, p < .01$). There was the main effect in the consistent perspective factor but no such effects in the suggestion factor($\chi^2(1) = 31.57, p < .01; \chi^2(1) = 2.87, p = .09$).

These results have several implications. The perspective changing performance of the No consistent perspective/No suggestion condition did not improve at all, compared to the conditions where minorities provided different perceptions or suggestions. This means that providing different perspectives and suggestions from minorities is an effective strategy for enhancing the perspective changing. An interesting point was found from comparing these results and the results of the problem solving performance described in the previous section. The simple main effects detected suggest that there were differences between Consistent perspective/Suggestion condition and No consistent perspective/Suggestion condition. This may mean that the synergies of the two factors (Consistent perspective/Suggestion condition) are effective.

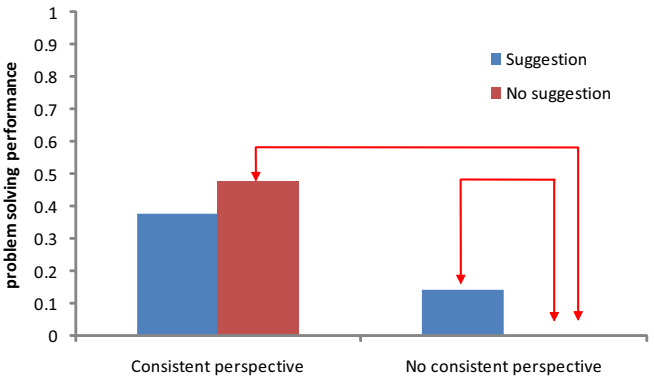

図 9 Results of the problem solving performance.

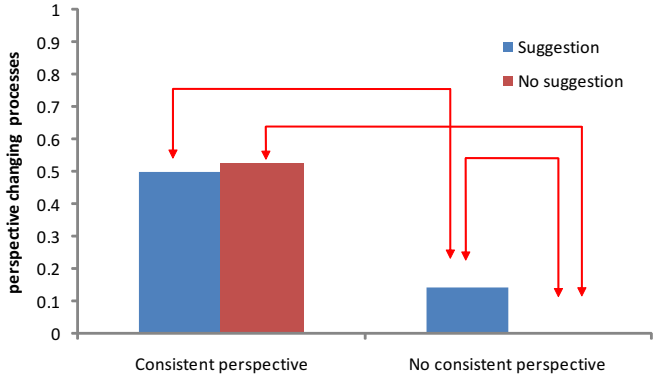

図 10 Results of the perspective changing process.

5. DISCUSSION

5.1 Effects of minorities with different perspectives

The results obtained suggest that using minority opinions in collaborative problem solving is an effective strategy for improving the collaborative problem solving performance and the perspective changing process. In the No consistent perspective/No suggestion condition, there were no participants who could find the solutions or change their perspectives. However, when participants collaborated with the minorities who communicated them different perspectives, the problem solving performance and the perspective taking process improved. These results show that creative perspectives emerge when minorities consistently take different perspectives. The past research on the minority effect has not been focused on natural collaborative problem solving environments. There were also few studies that focused on creative activities, such as collaborative problem solving. Therefore, this study offers new results for open-ended situations.

The obtained results also indicate that the two factors of communication behavior affect the problem solving performance and the perspective enhancing process and can be used for improving the collaborative problem solving performance.

No synergy of the two types of the perspectives on the problem solving performance was experimentally found, as was predicted in the beginning. The synergies of the two types of factors were however, found effective, when focusing on the perspective changing process. These results support our initial hypothesis and lead to speculations about how different perspective suggestions would make a break through during collaborative problem solving.

There are still unanswered questions that could affect the problem solving and the perspective changing process. These are about the social relationship between the collaborators, conversational manners of the minorities, dynamic size of the groups, etc. Is future work, we will investigate these issues.

5.2 Conversational Agents for supporting collaboration in groups

The results obtained in this study highlight the usefulness of minorities with different perspectives in collaborative problem solving. One important point is that conversational agents were employed that respond, based on simple rules. This suggests that there is a big potential to use such agents in different domains for supporting collaborative problem solving in groups.

Recently, there is a growing trend in the study of pedagogical conversational agents in collaborative learning and education[1]. Most of those studies have pointed to the importance of using animated characters to enhance motivations of the learners. There were few studies, however, that focused on communication behavior and the role of agents that help during collaborative problem solving. From the viewpoint of pedagogical conversational agents, this work suggests a useful way to employ conversational agents to model minorities. This should be used to motivate learners to consider problems from different perspectives. Especially, conversational agents could be used to promote a break trough in situations when problem solvers are fixated and biased to a typical perspective within a group. The use of such agents is not limited to education, as they could be applied in other domains to support divergent thinking and promote generating original ideas.

6. CONCLUSION

The goal of the present study was to investigate the effects of consistent different perspectives and suggestions were investigated during collaborative problem solving, when solvers are biased to a particular view point. The following three points were investigated: (1) Do different perspectives emerge when a member consistently takes different perspectives? (2) Do different perspectives emerge when minorities ask partners to provide explanations and suggestions?, and (3) Do the synergy of the above two factors enhance problem solving performance? To examine the effects we conducted an experiment, using conversational agents which played the role of human partners.

Results obtained in the experiment suggest that: (1) the problem solving performance and the perspective changing performance are improved when minorities consistently take different perspectives, (2) the problem solving performance and the perspective changing performance are improved when minorities provide meta suggestions, and (3) a synergy between these factors can lead to the emergence of new perspectives during collaboration.

7. ACKNOWLEDGMENTS

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