AWARENESS TOOLS AND MUTUAL MODELLING IN A COLLABORATIVE GAME

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This contribution aims to study the cognitive impacts of awareness tools in a collaborative game. We looked whether those tools have an effect on the representation an individual build of what his partner knows, plans and intends to do (i.e. mutual modelling) as well as on performance. Using such tools has a significant effect by improving task performance. However, players who were provided with this tool did not show any improvement of their mutual modelling. Further analysis revealed that there was an effect of the awareness tool on mutual modelling for players who spent a large amount of time using the tool.

INTRODUCTION

Over the last decade the level of interest in the field of CSCL has grown enormously and a ever increasing number of platforms have been developed with the goal of supporting collaborative learning. Those environments often support only one part of the collaborative process, that of bringing learners together. The problem is hence to overcome the computer limits so as to make cooperating participants and their activities visible to one another. This concept of understanding the partners' activities and interactions with the workspace is called awareness.

The concept of awareness has come to play a central role in CSCL because researchers and designers explore computational ways to offset the lack of information about the others in multi-user environments. That is why awareness tools (AT in the remainder of this document) are provided to show information about who is in the shared workspace, where are the partners, are they available ? what are the partners doing ?, etc.

Despite this growth of interest about awareness in the field of CSCW and CSCL, there are unfortunately few occurrences of research concerning the real impact of those AT. The little studies within this field tackles the problems of the use of AT (see Jang et al., 2002 for example) and usability issues (Gutwin et al. 1996; Gutwin & Greenberg, 1998). In order to bridge this gap, we would like to investigate the potential benefits of those AT by exploring whether they could facilitate the representation an individual build about his partner's actions, beliefs and intentions when performing a joint activity. This representation is called mutual modelling (from now on called MM). Therefore, we have investigated whether providing peers with AT can help building more accurate mutual models and being more effective as well. In order to reach that goal, a computer game was employed to conduct experiments. In

this game, two players located in different rooms are involved in a space mission where they were required to collaborate.

As a matter of fact, recent theories about collaborative learning describe it as a process of building and maintaining a shared understanding of the task (Roschelle & Teasley, 1995). This viewpoint hence assume that attention should be paid towards the collaborative interactions (explanation, argumentation...) through which peers build this shared comprehension. In addition, for detecting misunderstandings and disagreement during the interactions, the subjects must maintain some representation of what their partner understands. Therefore, it is meaningful to investigate the cognitive benefits of mutual modelling as it can be postulated that maintaining a representation of the other's viewpoint is an effort that could contribute to the learning process. Indeed, forcing the learner to estimate his partner's understanding of the situation could lead him to reason more deeply on the domain and to perceive the task from a second viewpoint. Thus, improving the mutual modelling process thanks to awareness tool could facilitate learning, or conversely by reducing the cognitive effort, decreasing the learning gains. This research, by exploring if we could augment mutual modelling with awareness tools, is a first step before focusing on the learning outcomes of building a more detailed partner model.

VARIABLES AND HYPOTHESES

Variables used

The presence or absence of the awareness tool constitutes the experimental condition of the study : it is our independent variable. In order to test our hypotheses, two dependent variables were used : task performance and mutual modelling. Concerning task performance, we used the pairs' score : player A's score added to player B's score. Concerning MM, two different questionnaires allowed us to calculate an evaluation the value of MM for a pair. First, during the game and for each of the three levels, players had to answer to two multiple choice questionnaires. Those questionnaires asked them about what they are intending to do at the moment (guiding his partner, trying to understand his strategy, trying to establish a common strategy, adjusting a shoot, etc.). Then, the questionnaires asked each player about what he thinks his partner is currently doing (same propositions as the previous questionnaire). We compared the first answer of a player (about what A is intending to do) to the answer of his partner to the second question (about what B believes A is doing). Consequently, our evaluation of the MM accuracy is the number of common answers to those two questions. We compared whether A's prediction of B's answer matches with B's actual answer. Hence, we could calculate three indexes : MMg (global mutual modelling evaluation for the pair), MM1 (Mutual Modelling evaluation for the pair measured in the first level) and MM3 (Mutual modelling evaluation for the pair measured in the third level).

Hypotheses

We postulate three hypotheses :

- Hypothesis H1 : Pairs with awareness tools are more effective than pairs without awareness tools. Indeed, the information brought by the AT can enable players to complete the task more efficiently. In order to evaluate the performance, we use the team score, sum of the two players' scores. Therefore, we expect that *the team score is higher when players have an awareness tool.*

- Hypothesis H2 : Pairs with awareness tools build more accurate model than pairs without awareness tools. *The global mutual modelling evaluation (MMg) should be higher when the players have an awareness tool*. The MMg is the sum of the objective evaluations of the mutual modelling of a team during the whole game, measured by the in-game questionnaires.
- Hypothesis H3 : the mutual modelling accuracy improves with time: when partners learn to know each other, the representation of each others' strategies is more accurate. As a consequence, *we expect MM3 to be higher than MM1*.

METHODOLOGY

The collaborative environment

SpaceMiners is a video game designed for running psychological experiments. It has been developed at the Geneva Interaction Lab (University of Geneva) by Yvan Bourquin, Jeremy Goslin and Thomas Wehrle. As can be seen on figure 1, the purpose of the mission represented here is to collect the largest amount of minerals located in asteroids and to bring them to the space station on the left. The score represents the number of collected minerals docked to the space stations launched by the two players. The score is influenced by several factors such as : the drone trajectory, the launch speed, the tools positions (that influence the drone trajectory), the number of asteroids in the environment, the planet positions (that modify the gravity). Even though SpaceMiners is a video-game, one should not think the task proposed is simple. The task is hard from a cognitive point and lasts for two hours.

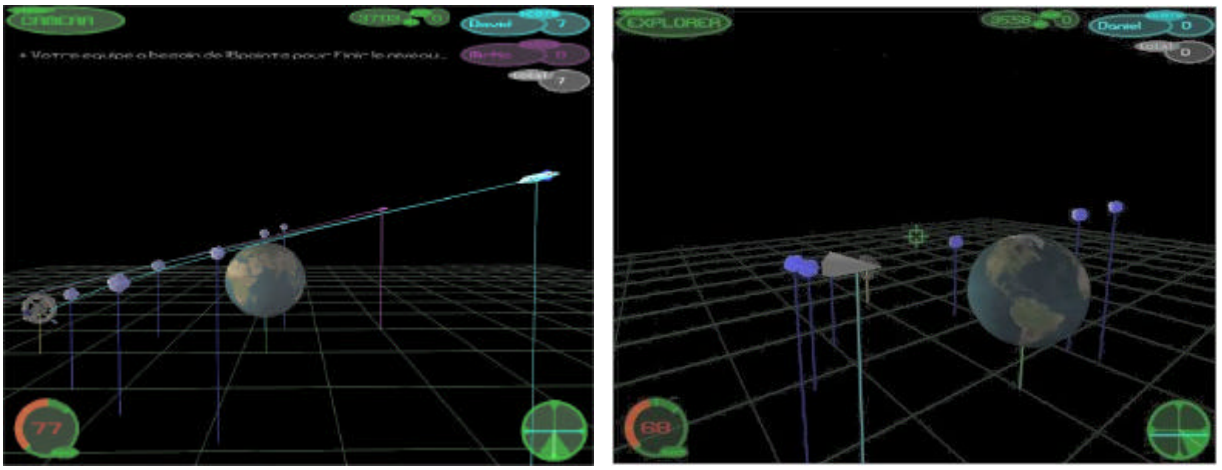

Figure 1: the game environment made up of a planet, asteroids, two spaceships and a space station. The right screenshot depicts the view as can be seen in the camera mode. It is the camera view (since we see the spaceship) as indicated in the upper left-hand corner. David (the player who controls the ship) manages to collect asteroids and to dock his drone to the space station. Thus he wins 7 points. On the left screenshot, we can see the spaceship view.

The users can play in two modes that corresponds to two viewpoints : the explorer mode and the camera mode. They can switch from one mode to another by pressing a key on the joystick. In the explorer mode, the position of the spaceship is fixed and players launch drones that pass through as many asteroids as possible on their way to the space station. Once the drones are launched players have no control over them. It depends only on the direction of the explorer and the launch speed of the drone controlled by the player and on the gravity of planets. In the camera mode, players can move their camera around in space by moving the

joystick. The camera is very useful to see space from another viewpoint and to place tools in space. The left screenshot in figure 1 shows the camera as it can be seen in the explorer mode. The right screenshot shows the space and the ship seen by the camera.

The awareness tool is the view of the partner's camera and his laser pointer as presented in the left screenshot in figure 1. By seeing the camera of his partner the player can obtain awareness information about his team-mate location and gaze. Thus he could help him to drop tools into space or to adjust his trajectory. There are two tools that can be dropped in space : the blackhole and the gate. The blackhole has a very high gravitational pull : it pull drones towards it. Gates are stabilized entrances to wormholes in space-time. If two are placed in space then a gate will transfer a drone from one position in space to another instantaneously. The tools available depends on the level of the game. In level one, players are given no tools. In level two and three, each player has different tools in order to foster collaboration between them.

Procedure and settings

Experimental subjects consisted of 18 pairs (N=18) composed of male students (in order to avoid gender bias) recruited on the university campus. These pairs were assigned to one of the experimental conditions forming two groups of 9 pairs. Participants were assigned a partner they were not familiar with. The game was played on two computers over the local network. Each player sit in front of a distinct computer located in different rooms and could communicate by voice thanks to headset. Experiments lasted approximately 2 hours and were conducted in French. After a tutorial, players had to complete three levels. Mutual modelling questionnaires were displayed during missions 1, 2 and three.

RESULTS

According to hypothesis H1, the awareness tool enables pairs to increase their performance. We want to test the effectiveness of using an AT. The descriptive statistics shows that pairs with AT reached higher score than the others. The mean score for pairs with AT is 258.67 (Std dev = 90.80) and 175.67 (Std dev = 67.48) for pairs without AT. Besides, no pairs without AT reached the mean score of the pairs with AT. the ANOVA test confirms that there is a significant differences between the two conditions ($F = 4.84$, $p = 0.043$). Therefore, our first hypothesis is validated : there is a significant effect of the awareness tool on performance.

Our second hypothesis H2 is that the use of an awareness tool improves the mutual modelling accuracy of a pair. We assume that players with awareness tool have more accurate mutual modelling, that is to say : MMg (With AT) > MMg (Without AT). The MMg means of the two groups are very close (1.63 for pairs with AT and 1.58 for the pairs without) but it is not the case of the standard deviation (0.48 for pairs with AT and 0.87 for pairs without). It goes against our hypothesis and the ANOVA test shows that H2 is invalidated ($F = 0.02$, $p = .889$). The use of the AT does not improve the accuracy of the mutual modelling. The representation of one's partner strategy is not facilitated by the information conveyed by the awareness tool.

Our third hypothesis assumes that there is an effect of time and collaboration on mutual modelling. At the beginning of the game, the players are not familiar with each other. We hence postulated that playing together during two hours enables them to improve the accuracy of their mutual modelling. We assume that MM3 which is the evaluation of the accuracy of

the mutual modelling measured in level 3 is higher than MM1 which is the evaluations of the accuracy of the mutual modelling measured in level 1. There is a slight difference between the means of MM1 (mean = 1.33 Std dev = 0.84) and MM3 (mean = 1.94 Std dev = 1.14). According to the test presented in table 16, concerning the effect of time on the accuracy of mutual modelling, it is only a trend (F = 3.189, p = 0.084) as depicted on figure 4. We reject H3 with p = 0.084. Additionally, there is no effect of the presence of the awareness tool (F = 0.105, p = 0.748). This result is consistent with the invalidation of our second hypothesis. There is also no interaction between time and the presence of the awareness tool (F = 0.105, p= 0.748). As a consequence, this supports the argument that the sudden increase of the accuracy of the mutual modelling is not due to the presence of the awareness tool.

DISCUSSION

Overall, our findings suggests the benefits of awareness tools on task completion. This result is consistent with the literature (Gutwin et al., 1996) ; Espinosa et al., 2000). They also found that awareness can be beneficial to team performance. This tool, by providing a continuous feedback to the partner about the player's location, is very useful. For instance, thanks to the AT, player A guided player B's movement by giving him instructions about where dropping the object. However, the results concerning the impact on the accuracy of the mutual modelling is not so easy to explain. We postulated the facilitation of the representation of one's partner strategy thanks to the information conveyed by the awareness tool. This second hypothesis is invalidated. Nevertheless, we also looked at the percentage of time spent in each view (camera or spaceship) by the pairs. We could hence notice an interesting difference. Additionally, a two-way analysis of variance showed that pairs in the awareness condition who spent more time in the camera mode reached higher levels of mutual modelling (F = 8.02, p = 0.015) than the others. Therefore, it implies that there is an effect of the awareness tool on mutual modelling only for the teams who spent a long time in the camera mode. Our third hypothesis was that the MM accuracy improves with time. There seems to be an effect but it is not statistically significant.

There are several limitations to these data and to the experimental design presented in this report : the low number of participants (nine pairs in each conditions) and the method used to measure the accuracy of the mutual modelling for instance. We should use a more objective method to evaluate this variable. One possible analysis is to look at the activities : whether they are sequencialized and to what extent they are balanced. It should be relevant to have an indicator that tells us whether the players coordinated their activities. Additionally, our questions just dealt with information at the behavior level. We should have used indications at the knowledge ("Does you partner understand the gravity concept ?") or strategy level ("Among the following strategies, which one describe the best your partner's strategy ?").

Our finding also raises a new question : do players really used the awareness tool ? Indeed, if there is an effect of the tool on mutual modelling only for the players who used it frequently, it may be possible that only a few players in the tool condition noticed the advantage of using it. It hence could be an interesting for practitioners. They indeed should keep in mind that players do not AT systematically. As we have seen in our experiment, several players did not really notice the potential of this tool. Thus, they should provide users with usable AT and teach them their real value. Concerning collaborative work, the use of the awareness tool could lead to transform a task from a verbal to a visual activity and the pair is thus more effective because A has not to describe where he is and B has not to interpret this description.

This study has shown that it seems possible to augment mutual modelling with computational tools. A pre-requisite in our environment would be to explain to the players the value of the awareness component as well as teaching them how to use it. We could now consider new research avenues to clarify our vision of mutual modelling. For example, it could be interesting to consider the rate of redundant actions in the game or to to look at the pairs' dialogues to complete our study of mutual understanding. The next step will be to analyse the potential learning gains of improving mutual modelling .

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