The Underwhelming Effects of Location-Awareness of Others on Collaboration in a Pervasive Game

Nicolas NOVA[a,1], Fabien GIRARDIN[b], Gaëlle MOLINARI[a] and Pierre DILLENBOURG[a]

[a]*CRAFT, School of Computer Sciences and Communication, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland*

[b]*Interactive Technology Group, Dept of Technologies, University of Pompeu Fabra, Spain*

Abstract. In this paper we seek to empirically study the use of location-awareness of others in the context of mobile collaboration. We report on a field experiment carried out using a pervasive game we developed called CatchBob!. Using both quantitative and qualitative data, we show the underwhelming effects of automating location-awareness. Our results indeed shows that automating this process does not necessarily improve the task performance and that it can be detrimental to socio-cognitive processes involved in collaboration such as communication or the modeling of partners' intents. The paper concludes with some potential impacts for location-based application practitioners.

Keywords: location-awareness, socio-cognitive processes, pervasive game, cscw, field experiment.

Introduction

One of the most promising domains of Computer Supported Cooperative Work lately has been the emergence of a new class of mobile applications called 'location-based services' (LBS in the remainder of this document). These LBS take advantage of people's physical location to provide users with various services. The actual utility of such applications in mobile systems has been demonstrated in a wide range of application examples, in obvious domains such as fieldwork [1] and tourism [2], as well as mobile gaming [3]. Among all of those services, one of the most obvious features behind LBS is positioning and tracking of individual. Such systems allow users to find and track a person, a group or an artefact. They offer both synchronous and asynchronous information about the location of people or objects in the physical environment. Consequently, these services raise important issues in terms of cooperation; our research helps to clarify this issue by looking at how it impacts group interactions.

[1]Corresponding Author: CRAFT/EPFL Station 1 Ch-1015 Lausanne, Switzerland; E-mail: nicolas.nova@epfl.ch

LBS raise interesting problems already approached by the CSCW community: the awareness issue and how it influences collaboration. Dourish and Belloti have given one of the best-known definitions for this very concept: "*awareness is an understanding of the activities of others, which provides a context for your own activity*" [4]. Drawing on this definition, location awareness would be "the understanding of the others' position" in the spatial environment. Moreover, Gutwin and Greenberg insisted on the knowledge dimension of awareness [5]. They indeed stated that it is knowledge about a state of the work environment in a limited portion of time and space. Since there is a lack of awareness information in computer supported environments, designers hence provided users with tools to support this functionality. Those tools are supposed to facilitate team collaboration by showing information about presence (is anyone in the workspace?), their identity (who is that?), their location (where is an individual?), their action (what is somebody doing?), and so forth. In this context, making others' position available on a mobile device is a way to gather and broadcast some specific kind of information on the 'where' category: location awareness. From the user's point of view, we could define it as *the appraisal and the understanding of information about the spatial positions of the partner(s) in the environment*. Some studies in virtual environment tackled this issue by showing that people pay attention and benefit from knowing their partners' spatial location when carrying out a joint activity. In a study about virtual textual reality better known as MOO, it has been shown that location awareness supported implicit coordination and division of labour among the group [6]. A previous project we had conducted about 3D virtual games [7] also revealed that providing players with spatial information enabled a better performance to the game task and improved the construction of the representation an individual build of his/her partner's strategies and intents. Those studies revealed to what extent knowing the partners' whereabouts can positively affect collaborative processes involved during group collaboration: processes which support the performance of a joint activity by a group of people [8]; that is to say all the socio-cognitive interactions such as the division of labour among the partners, the establishment of a shared understanding, communication, coordination strategies or mutual modeling (i.e. inferences made by each of the individual about their team-mates' intents, beliefs, and goals) [7].

Surprisingly, there seems to be little research so far about the very topic of collaborative processes in a context of location-based applications usage. The existing studies about it put more emphasis on the design aspects than on the empirical investigation of how users' behaviour is influenced by knowing where the partners or the competitors are located. With regard to this lack, our focus in this paper is to present a study which aimed at investigating the impact of location-awareness on group processes in mobile settings. It addresses the way it might influence collaboration processes such as mutual modeling and communication.

This paper first describes the existing projects that addressed how those aforementioned socio-cognitive processes are impacted by mobile technologies and LBS. The second section presents our research scope as well as the platform we designed to fulfill our needs. After a presentation of the main results, the final section discusses the potential outcome and their consequences for practitioners.

1. Related work

Although most of the literature about LBS is technology-driven, it is a rapidly moving field and there is now some established research projects geared towards the understanding of location-awareness usage. Scholars recently focused on the use of location information in a mobile context in cell phone conversations. One of the most common features of those conversations is the giving of a geographical formulation as part of an opening of a phone call; to answer to the famous "Where are you?" question. In a study of cell phones users [9], Arminen found that strict geographical location is relevant only on few instances, such as instructing somebody on how to find place X. Weilenmann also revealed in her analysis of recorded mobile phone conversations, that location was relevant only to plan a future meeting [10]. Then, it seems that in terms of problem solving, giving one's location is useful for group coordination to meet each other. The location is relevant for the parties involved in the conversation as formulated by Arminen. Besides, drawing on ethnographic studies of mobile workers Laurier pointed out that these "locational formulations" allow dispersed cell phone users to mutually establish and share a spatio-temporal context [11]. An Australian study also looked at the usability of SMS used in a group rendezvousing and wayfinding activity [12]. Given that users had to figure out the approximate location of their partners as well as developing a representation of the area being explored, they sometimes misattributed delays and formed inaccurate models of behavior/location. Recently, Intel designers developed a system that would support both manual and automatic location disclosure on cell phones [13]. They found that automating this process, while at times valuable, suffered because the explicit communication act by the sender and its accompanying knowledge of intended context for interpretation was lost.

However, it is certainly in the field of mobile computing that location-awareness usage has recently been more investigated. Obviously most of studies focused on location-based services usage and how location-awareness impact individual or collaborative behavior has been conducted using games [14] [15] [16] [17] [18] in which the task is often about wayfinding, finding and collecting objects or rendezvousing. At the sociological level, [18] studied a location-based game deployed in Japan called Mogi Mogi[2] in which players have to collect virtual and localized artefacts in Tokyo. The authors noticed that knowing the others' positions on the screen of the cell phone created an affordance for social encounters and then led to specific forms of conversational openness. Investigations at smaller group levels also shed some light on this phenomenon. An experiment of a location-awareness tool in museum settings showed that location was a powerful resource for collaboration [19], since it eased referential communication, by allowing people to better understand what their partners were looking at. Moreover, experimenters found that location-awareness allowed participants to quickly find what their friends were looking at and hence find them too look at the same thing. Another study examined how location-aware technology impacts social behaviour within the context of rendezvousing (meeting at an agreed upon time and location) [20]. Three different technology conditions were investigated: mobile phones, PDA displaying location information of others and both mobile phones. All of the groups were able to complete the rendezvous tasks without much difficulty but participants exhibited very different behaviours depending on the

[2] http://www.mogimogi.com/

technology used. The location-awareness feature was very good at gathering contextual information, such as location, in a very unobtrusive manner but it provided little assistance to users in interpreting the associated state of the person.

Among the issues related to location-awareness usage, different studies explored the notion of uncertainties due to technological pitfalls [21][3][22]. These investigations bring forward the fact that ubiquitous computing is still a maturing field in which lots of problems may arise like unreliable network, latency, bandwidth, security, unstable topology, or network homogeneity. Consequently, users learn or set strategies to adapt or to rectify the aforementioned systems failures. One of the solutions to overcome problems due to location awareness discrepancies is to let users manually reveal their positions as reported by Benford et al. [14], which happened to be quickly learned, by users. In this study, authors found that rather than reporting themselves to be at a different place, the users were in fact reporting themselves to be at a different time. The result also showed that self-revealing a position is an act of communication (not only x and y coordinates or a place name) that can reveal past or future intentions. However, the limitations of those self-reported positioning are that the mobile player had to know where they were and/or where they were heading, which is not always the case. Finally, a Wizard-of-Oz study revealed that giving information about the proximity of a searched object can reduce the searchers' walking distance to the object but also that it may increase the search time [23] if the system demands too much of the user's attention.

Other research, which deploy game to understand location-based services usage, do not directly put the emphasis on how location-awareness modifies collaboration. They instead focus on tactics developed in a mobile setting [16] or on the difficulty to represent group formation on the display [15].

2. Research scope

In the previously mentioned studies, the effects of location-awareness of others are often addressed only as a side investigation of the research project. Our focus is to tackle this issue more deeply, dealing with their potential effects on collaboration processes we defined in the introduction: the socio-cognitive interactions involved when people collaborate. This study aims at investigating whether location cues influence collaboration processes such as the task performance, mutual modeling, and communication. Our point here is to deepen the results described in the previous section, expanding these issues through the use of a different methodology. We indeed rely here on a field experiment based approach [24]. As a matter of fact, field experiments are quantitative experimental evaluations that are conducted out in the field, drawing from aspects of both qualitative field studies and lab experiments. They take advantage of both qualitative and quantitative studies. On the one hand it involves real users in an activity that occurs in the real world. On the other hand, we can control variables and have different experimental conditions. In order to conduct such a field experiment, we decided to use a collaborative mobile game for three major reasons. The first one is because a game, especially a mobile computing one, involves participants in a real context (the physical world) with a certain ecological validity. A game in public space indeed creates a certain kind of complexity with passers-by or real-world features; for example participants are not free since they have to take the environmental topology into account; they also have to pay attention to systems uncertainties (disconnection, network availabilities…) as in the real world. Second, the task domain in games is easier for both the participants and the experimenters (compared to firefighters emergency missions for instance). The learning curve is way softer. Finally, it is better to make participants doing a game than a really complex task they will never carry out. Then, we expected participants of this game to have a better implication than in a complex task.

The empirical study presented hereafter is an exploratory investigation that engages participants to collaborate in the achievement of a spatial coordination task. The presence or absence of the location-awareness tool constitutes the experimental conditions of the study.

3. Methodology

3.1. A pervasive game as a testing platform: CatchBob!

CatchBob! is a mobile game in which groups of 3 teammates have to find a virtual object on our campus at EPFL in Lausanne. The dimensions of this 'field' are 850x510meters. Completing the game requires the players to surround the object with a triangle formed by each participant's position in the real space. To reach this goal, they employ an application running on Tablet PCs as depicted on Figure 1.

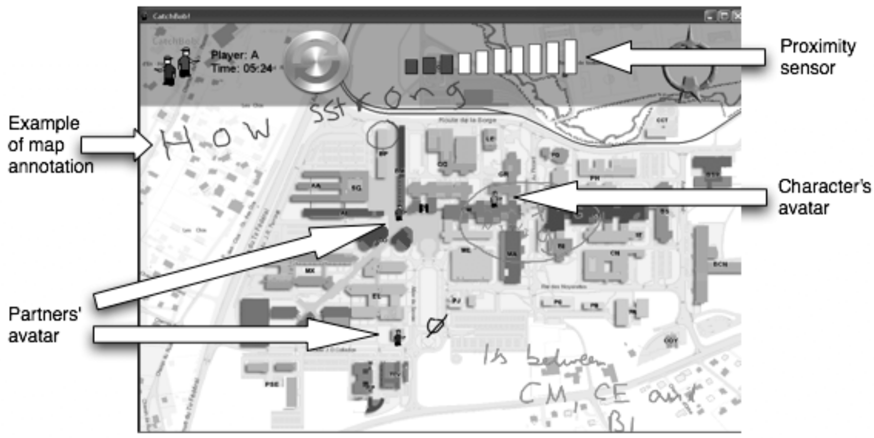


Figure 1. CatchBob! interface as seen by one player. This snapshot depicts the interface with the location-awareness tool: Avatars of other players are displayed. In the condition without the location-awareness tool, the interface only displays the character's avatar.

Another meaningful piece of information given by the software is an individual proximity sensor. It indicates whether the user is close or far from the object through the number of red bars displayed at the top of the interface. There is actually no object on the field; it only appears on the screen when the users are close to it. In addition, the tool also enables communication: Players can synchronously annotate the map with the stylus. The annotations slowly fade out until they become completely invisible (after 4 minutes). This leads to very simple acts of communication and dialogues; for instance a player asks his or her teammate to move to a specific direction with an arrow with the message "go there" and the partner acknowledge this advice. When the players are close to the object, the triangle they have to form appears on the display; they then have to adjust it in a proper way.

In the experimental condition "without the location-awareness tool", players just see their own character as an avatar on the campus map. In the condition "with location awareness", player could update his or her partners' positions by clicking on a refresh button.

Even though finding the object could be carried out alone, the collaboration in this game lies in the fact that players have to coordinate to form the triangle surrounding the virtual object. It is not possible to complete the game without collaborating. We hence avoid the free rider effect.

All the players' interactions with the applications (positions, annotations, getting others' positions, connection loss) are logged on a server. We also developed a replay tool that allows to show the paths of each player. This application allows us to confront the players to a replay of the path they took during the game, as well as the actions they performed.

3.2. Procedure and participants

Sixty students of the Ecole Polytechnique Fédérale de Lausanne (age range: 19-27; mean: 22.8) participated in this experiment. We had 10 groups of 3 persons in the condition "with awareness tool" and 10 groups in the condition "without awareness tool". All the group members knew each other because different levels of knowledge between partners may impact the representation each of them have about their teammates. Players were also all familiar with the campus. Experiments lasted approximately one hour and were conducted in French. The experiments were run on our campus, one group at a time.

Participants were asked to find the virtual object and surround it with a triangle made by their position with one constraint in mind: They should take the shortest path to it. We also told them that the goal was not to find the object in the smallest amount of time.

After presenting the game instructions at the lab, players were given 3 minutes to plan their strategy on a map. Players were then led to the common starting point at the centre of the campus. They had 30 minutes to complete the task, which is quite sufficient to achieve the goal without a too tight time-pressure, judging from the pretest we ran. After completing the game (or playing 30 minutes), players returned to our lab and filled a post-game questionnaire during 10 minutes. This questionnaire provided participants with 3 maps of the campus on which they had to draw their path as well as paths followed by the 2 partners. Players were also asked questions about how was the collaboration, if it was balanced or not, whether they had fun playing the game and if they understood their partners' intents during the joint task. The last part of the study is a structured interview, during which players are confronted to a replay of their activity; the group had to answer questions about coordination strategies, communication acts, the paths they took, the tactics they deployed as well as describing the misunderstandings and negotiations that happened. The replay tool functions like a basis to foster players' verbalizations; it shows the players' paths and their annotations on a map of the campus.

We controlled several variables like the number of participants among the group, the fact that they knew each other as well as the field, they had the same gear (a Tablet PC, no cell phone, no walkie-talkie) and they had all the same starting point. In addition, we used two different positions of "Bob". There is the same number of games with these 2 positions in each of the conditions. The distance between the starting point and Bob is the same in these 2 scenarios. We controlled that the position of 'Bob' had no effect on the dependent variables presented in the next section; which was not the case.

3.3. Extracted data

The CatchBob! platform allows us to collect a wide set of data ranging from quantitative measures to players' interview and account of the game. Quantitative data refers to both task performance and collaborative process indexes. Measuring performance is done through the sum of the path length over all players in a group. We did not choose time as a performance variable since we did not want players to run on the campus with Tablet PC and because finding a proper path was better suited to the discussion of a relevant strategy. With regards to the socio-cognitive processes involved, we measured three kinds of variables:

- The frequency and the content of annotations written on the Tablet PC reflect the communication among the group (no audio communication occurred since the only way to interact was using map annotations). The coding scheme adopted to describe the annotations content is explicated in section 4.2.
- The number of errors they made while drawing the path of their partners after the game is an indication of how each player modelled the activity of their partners. We indeed asked players to draw their path on a paper map as well as the paths of their partners, as described earlier. We could hence make comparisons between the path player A drawn about B or C to B or C's real paths. This comparison, measured by the number of mistakes, represents the quality of A's representation of B and C's behaviour in space. This is a measure of the 'mutual modeling', that is to say the inferences made by each of the individual about their teammates' whereabouts. Asking one person to draw his or her own path is a way to judge the competence to draw a trajectory.

On the other hand, the qualitative data we get range from the coding of map annotations to players' verbalizations when confronting to the reply tool after the game. Those data allow us to reconstruct the game experience and to give more sense to the three players' actions in the various phases of the game.

4. Results

4.1. Performance and modeling the partners' trails

Since it was a collaborative game, we analyzed the task performance at the group level, which corresponds to the group travel distance. As depicted on Figure 2a, groups in both conditions have a very close performance; the only difference lies in the dispersion that is higher for players without the automatic display of the partners. A oneway-ANOVA test did not show significant differences ($F = 0.07$, $p = .78$).

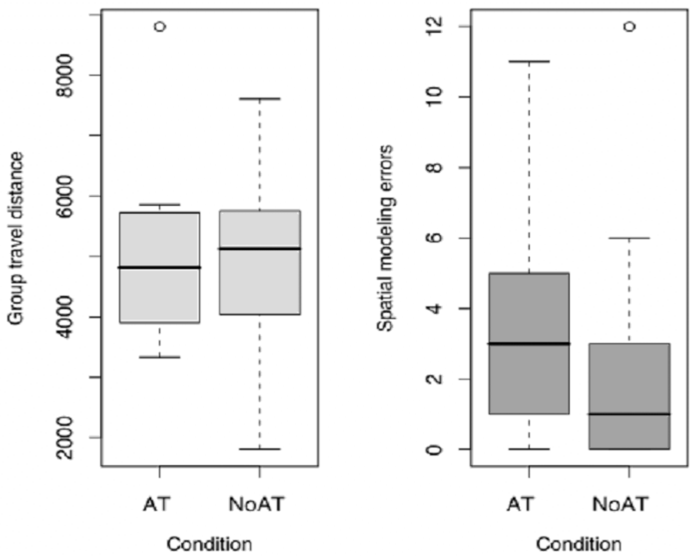


Figure 2. (a) group travel distance in the two experimental conditions (AT: with the location awareness tool; NoAT: without the location awareness tool) (b): number of errors made by each participant during the post-test (while drawing the path of the partner) in the two experimental conditions.

As mentioned in the section about the experiment procedure, we measured the number of errors between the path player A drawn about B or C to B or C's real paths. This mutual modeling index represents the quality of A's representation of B and C's behavior in space. We did that for each player. Figure 2b shows the number of errors in each condition. This variable has been analyzed at the group level. As described by [25] we checked the non-independence of the results through the computation of intraclass correlation ($r = .39$), which is significant ($p = .01$). That expresses the non-independence of the results among groups. It means that the number of errors made by the subjects is dependent on the number of errors did by the partners (e.g. if one player made a lot of errors about his/her path, the same goes for the partners). Then the unit of analysis is the group. Players without the location-awareness tool make two times fewer errors than those who had it as attested by the Wilcoxon test we conducted (because data were not distributed normally): $W = 81$, $p = .02$. In other words, people among groups without the display of location information better recalled their partners' trails: their mutual modeling of their partners were better. This result, which is quite surprising, will be explained by the next findings.

4.2. Communication through map annotations

4.2.1. Annotations frequency

Map annotations have been investigated both by quantitative measures like the frequency and qualitative dimensions such as the content or the pragmatics of the messages. This variable has been studied at the individual level since the intraclass correlation among the group is not significant (r = -0.21 p = .87). Figure 3 shows the frequency of messages sent by each player in both experimental conditions. The frequency of messages is higher in the "without the location-awareness tool" condition. A Wilcoxon statistical test shows that this difference is significant: W = 55.56, p < .01. We used a non-parametric test because data were not distributed normally (Wilcoxon's test).

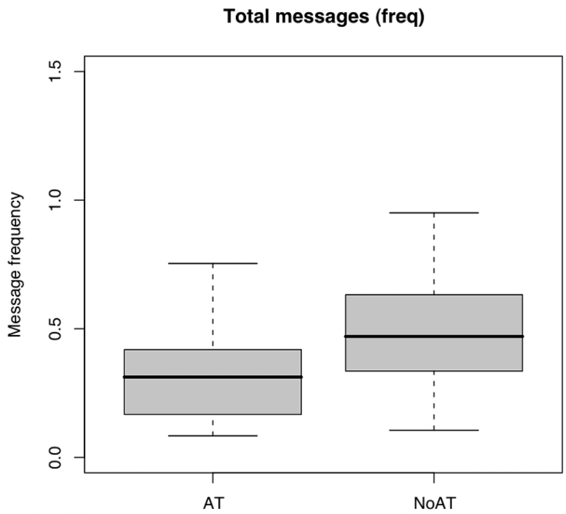
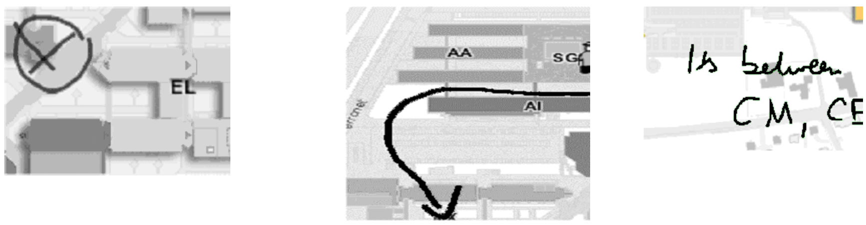


Figure 3. Frequency of map annotations written on the Tablet PC by each individual.

4.2.2. Annotations coding scheme

We developed our own coding scheme to categorize map annotations depending on the content of the messages (position/direction/strategy/proximity to the object/off-task/corrections) and also their pragmatics (announcement, order, question, and acknowledgement). Figure 4 presents examples of the aforementioned categories. We analyzed these annotations at the individual level. Inter-judge reliability of the coding system showed a Cohen's Kappa [26]of 0.89 for the content variable, a kappa of 0.86 for the pragmatics variable. The content analysis revealed that the frequency of messages about position (W = 203, p < .01) direction (W = 292, p = .01) and strategy (W = 269, p < 0.01) was higher in the condition without the awareness tool. There were not differences for messages about proximity to the object, off-task notes and corrections. In terms of pragmatics, players without the location-awareness tool sent more announcement (W = 253, p < .01) and more questions (W = 228.5, p < .01). There were no significant differences concerning the number of orders or acknowledgements. In addition, we found a negative correlation between the frequency of messages about strategy and the number of errors made by the individual when drawing their partners' path: Pearson bivariate correlation r = -.51 (significant p < .001).



Message about position: the character gives his positions to the partners with this cross.

Message about direction: the player shows her next move through this arrow.

Message about strategy: telling the partners that the object might be located between two buildings.

Message indicating the proximity to the object: indication of the figures given by the proximity sensor.

Off-task message

Correction message: by striking out a map area with slanted lines.

Figure 4. Examples of messages of each categories described in the coding scheme.

4.2.3. Post-hoc analysis

We performed a post-hoc split of groups into two kinds of participants accordingly with the repartition of errors made by a player to draw their partners' trails (i.e. the mutual modeling index). For that matter, the split point was the mean of errors. This split showed that persons who had a good representation of their partners' whereabouts sent more messages about strategy (W = 725, p < .0001), more questions (W = 614, p = .03) and orders (W = 664.5, p = .0003). We also found an interaction between the experimental variable (awareness tool presence), the number of errors and the strategy messages as represented on figure 5 (F = 7.2626, p = .009277). Players without the awareness tool wrote more strategy messages and so did those who had a more accurate mutual model (i.e. those who better recalled their partners' trails).

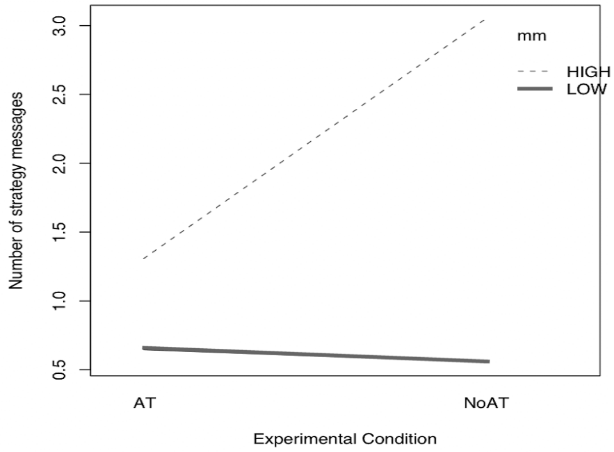


Figure 5. Interaction plot between the number of strategy messages, the two groups split according to the mutual modeling index (i.e. the repartition of errors made by a player to draw their partners' trails) and the experimental condition (with our without the awareness tool).

Simple effects of the interaction showed that the differences were significant for both experimental conditions: for groups with the AT, those who had a les accurate mutual model of their teammates (i.e. who did not recall the path of their partners very well) wrote less messages about strategy than those with a high mutual model (p = .01). The same goes for groups without the location-awareness tool (p = .0001). In addition, for people with a more accurate mutual model, the number of messages about strategy was higher in the condition without the location-awareness tool. And this is not the case for groups with the tool. In sum, removing the automatic display of partners' positions only impacted groups with a high mutual model of their teammates and not the others who did not recall their path very well. Besides, the difference between the number of messages about strategy sent by players without the AT might explain the wide dispersion about their performance (as seen on Figure 1).

Moreover, a post-hoc split of participants into two groups depending on the number of strategy messages sent by each participant showed that there is a significant difference in terms of errors. People who wrote a lot of strategy messages made fewer errors (W = 465.5, p < .001), which is not too much of a surprise since we found a high negative correlation between the number of errors and the number of frequency messages. There is no interaction between the experimental condition, the two classes of individuals (depending on the number of strategy messages they sent) and the mutual modeling index represented by the number of errors. Unlike players with a high mutual model, player who did lots of errors while drawing their partners' path sent few messages about strategy.

This means that the mutual modeling process depends both on the number of strategy messages sent by players and the absence of the location-awareness tool. But it seems that the most important factor is the exchange of messages about strategy since the presence of the awareness tool inhibited the writing of those annotations.

5. Discussion

Our study has revealed the underwhelming effects of automating location-awareness of others in a mobile collaboration context. As a matter of fact, we found that participants who were automatically aware of their partners' location did not perform the task better than other participants. In addition, people among groups without the location information built a more accurate mutual model since they made fewer errors when drawing the path of their partners after the game. A good mutual model is also shared among the group: when one of the teammates had a good representation of the others' whereabouts, it also held for the partners. These results can be explained by the messages exchanged. First the amount of messages is more important in the group without the location-awareness tool: players had then more traces to rely on in order to recall the others' trails. And when we look at the content, we see that players without the location-awareness tool sent more messages about position, direction or strategy. They also wrote more questions. Strategy was certainly the most important factor for the construction of the mutual modeling as attested by the post-hoc analysis. Finally, a very intriguing result is the fact that the presence of the awareness tool inhibited the writing of those annotations. By 'underwhelming', we refer to the fact that automating the location-awareness process not only undermines the exchange of messages about position but also about other kinds of information such as strategy or direction. As a consequence, the automatic awareness tool seems to make users more passive.

It appears that players without awareness tool took better advantage of the annotation capabilities, using it to express their path and their strategy. The players with the awareness tool were able to annotate as well but did not use this opportunity. There seems to be a certain inertia caused by the presence of location awareness information. We can then conclude that in the context of this experiment it was better to leave users without the location-awareness tool, with a broad channel of communication. They chose the information they perceived as relevant (position, direction and strategy) and sent them to their partners at the moment they wanted it to be known by the others. This is ostensive communication as described by [27]: the self-expressed position is both an attractor for others' attentions and a way to show the communicator's intent through messages about strategy or directions. Users could indeed express what they found relevant for the current task: with regard to the content (their position, direction, strategy messages) and to the pragmatic level (questions). This finding confirmed what [14] revealed: self-reported positioning could be reliable low-tech alternative to automated systems like GPS. However, our findings goes further by proving that letting user declare themselves their position is better with regard to various processes like communication or the construction of a mental model about the partners. These results also means that CatchBob! players anticipated something: they had to send more information otherwise the interpretation space for the others would be too small. That is why they sent messages about their direction and about strategy: the other teammates can then better infer what to do, and consequently build a more accurate mutual model.

Apart from issues regarding the field experiment paradigm, one of the limits of our study is that each group played only one game, which might be an issue in terms of interface learning. One possible response to see whether the results still hold over time is repeated play as described in [16] or a crossed experiment in which players from one condition play a second game in the other condition. Another critique is that, in this paper, we considered the task as a whole; there are actually different phases in which the effects of the location-awareness tool might be different: the exploration part, the rendezvousing moment and then the triangle formation. There might be some positive effects of the tool depending on both subtasks features and specific moments of the game.

That is the reason why future work will be directed towards the analysis of the three phases players has to achieve to complete the game. The point would then be to discriminate different impacts of the location-awareness features depending on the subtasks characteristics. Moreover, we will also investigate other collaborative processes impacted by the tool such as the division of labor among the group or the coordination strategies used over time.

6. Impacts for mobile and collaborative application practitioners

Despite the potential limitations of this study, it already surfaces key problems with location-awareness usage. Our field experiment shed some light on the idea that automatically broadcast information about whereabouts should be used carefully. It might indeed be detrimental to some collaborative processes such as mutual modeling or communication. The main lessons for practitioners are twofold.

First, automating a process such as location-awareness is not always fruitful. Letting people build their own representation of the spatial information appears to be more efficient than broadcasting mere location information. To some extent, not giving location-awareness information can be a way to support collaboration more effectively; since players may communicate more and better explain their activity and intents. Self-disclosure can hence be more effective since users could express both information about their intents relevant for the task context and their location. They could also send it whenever they want to express either their current or past positions or the intended places they are heading to. Another interesting benefit of letting the users express their position is to give them the control of privacy issues, one of the major issue related to LBS usage. They have indeed the choice to disclose information about their whereabouts, which is of tremendous importance to avoid the users' perception of privacy invasion as revealed in [13].

Additionally, though location-awareness is an important issue for mobile collaboration, it should certainly not be limited to a simple broadcast of people's position. The field experiment showed that communication about strategy was more important than automatic location-awareness for building a good mutual model. During this spatial coordination task we saw that players without location-awareness tool built a more accurate representation of their partners' paths partly thanks to these messages. They also facilitated knowledge elicitation: without the automatic location-awareness, subjects were more articulate about their strategy. It was as if the tool created certain inertia among the group, with regard to communication. Participants who relied on the automatic positioning wrote few messages, which lead them to be less explicit the situation and how they could deal with it.

References

[1] J. Pascoe, D.R. Morse, and N.S. Ryan, Developing personal technology for the field. *Personal Technologies* **2**(1)(1998), 28–36.

[2] K. Cheverst, N. Davies, K. Mitchell, A. Friday and C. Efstratiu, Developing a context-aware electronic tourist guide: some issues and experiences. *Proceedings of the CHI'00 Conference on Human Factors in Computing Systems,* 1-6 April 2000, pp. 17–24.

[3] S. Benford, *Future Location-Based Experiences*. JISC Tech Report (TSW0501), 2005.

[4] P. Dourish, and V. Bellotti, Awareness and coordination in shared workspaces, in J. Turner & R. Kraut (eds.), *Proceedings of ACM CSCW'92 Conference on Computer Supported Cooperative Work*, Toronto, Canada, 1992, pp.107-114.

[5] C. Gutwin, and S. Greenberg, S., A Descriptive Framework of Workspace Awareness for Real-Time Groupware, *Computer Supported Cooperative Work* **11**(3) (2002), pp. 411-446.

[6] P. Dillenbourg and D. Traum, The role of a whiteboard in a distributed cognitive system. Paper presented at the Swiss workshop on collaborative and distributed systems. (Lausanne, Switzerland, May 1st 1997), Retrieved from the Internet (October, 17, 2005) http://agora.unige.ch/conferences/Lausanne97/dillenbourg/

[7] N. Nova, T. Wehrle, J. Goslin, Y. Bourquin and P. Dillenbourg, P. The Impacts of Awareness Tools on Mutual Modelling in a Collaborative Video-Game, in *Proceedings of the 9th International Workshop on Groupware*, Autrans, France, September 2003, pp. 99-108.

[8] P. Dillenbourg, What do you mean by collaborative learning?, in P. Dillenbourg (Ed) , *Collaborative-learning: Cognitive and Computational Approache*s, Oxford: Elsevier, 1999, pp.1-19.

[9] I. Arminen, Location: a Socially Dynamic Property - A Study of Location Telling in Mobile Phone Calls, in L. Haddon et al. (eds.) *The Good, the Bad and the Irrelevant: The User and the Future of Information and Communication Technologies Conference Proceedings*, Helsinki, 2003.

[10] A. Weilenmann, "I can't talk now, I'm in a fitting room": Availability and Location in Mobile Phone Conversations. In *Environment and Planning* A volume 35, (9) September, pp. 1589 - 1605, special issue on Technology and Mobility, ed. E. Laurier, 2003.

[11] E. Laurier, Why people say where they are during mobile phone calls, *Environment and Planning D: Society & Space* **19**(4)(2001), 485-504.

[12] J. Axup, S. Viller, and N. Bidwell, Usability of a Mobile, Group Communication Prototype While Rendezvousing, in *Proceedings of the Symposium on Collaborative Technologies and Systems - Special Session on Mobile Collaborative Work*, St. Louis, MO, USA, May 15-20, 2005.

[13] I. Smith, S. Consolvo, A. LaMarca, J. Hightower, J. Scott, T. Sohn, J. Hughes, G. Iachello and G.D. Abowd, Social Disclosure Of Place: From Location Technology to Communication Practices, in *Proceedings of Pervasive 2005*, Munich, Germany.

[14] S. Benford, W. Seager, M. Flintham, R. Anastasi, D. Rowland, J. Humble, D. Stanton, J. Bowers, N. Tandavanitj, M. Adams, J. Row-Farr, A. Oldroyd, and J. Sutton, The Error of Our Ways: The Experience of Self-Reported Position in a Location-Based Game, in *Proceedings of Ubicomp 2004 Conference on Ubiquitous Computing*, Nottingham, UK, 2004, pp. 70-87.

[15] S. Benford, D. Rowland, D. Flintham, A. Drozd, R. Hull, J. Reid, J. Morrison, and J. Facer, Life on the edge: supporting collaboration in location-based experiences. In *Proceedings of CHI 2005 Conference on Human Factors in Computing Systems*, Portland, USA, 2005, pp. 721-730.

[16] L. Barkhuus, M. Chalmers, P. Tennent, M. Hall, M. Bell, and B. Brown, Picking Pockets on the Lawn: The Development of Tactics and Strategies in a Mobile Game. In *Proceedings of Ubicomp 2005 Conference on Ubiquitous Computing*, Tokyo, Japan, 2005, pp. 358-374.

[17] M. Chalmers and A. Galani, Seamful interweaving: heterogeneity in the theory and design of interactive systems, in *Proceedings of the Conference on Designing Interactive Systems* 2004, Cambridge, USA, pp. 243-252.

[18] C. Licoppe and Y. Inada, "Seing" one another onscreen and the construction of social order in a mobile-based augmented public space: The uses of a geo-localized mobile game in Japan, in *Proceedings of Learning in the Mobile Age Conference*, Hungarian Academy of Sciences, April 28–30, 2005.

[19] B. Brown, I. McColl, M. Chalmers, A. Galani, C. Randell, and A. Steed, Lessons from the lighthouse: Collaboration in a shared mixed reality system. In *Proceedings of the CHI 2003 Conference on Human Factors in Computing Systems*, Fort Lauderdale, Florida. ACM Press: NY, 2003, pp. 577–584.

[20] D. Dearman, K. Hawkey, and K.M. Inkpen, Effect of location-awareness on rendezvous behaviour. *CHI Extended Abstracts,* 2005, 1929-1932.

[21] G.D. Abowd, C.G, Atkenson, J. Hong, S. Long, R. Kooper, and M. Pinkerton, Cyberguide: a mobile context-aware tour guide. *Wireless Networks* **3**(5) (1997), 421–433.

[22] S. Antifakos, A. Schwaninger, and B. Schiele, Evaluating the Effects of Displaying Uncertainty in Context-Aware Applications, in *Proceedings of the Ubicomp 2004 Conference on Ubiquitous Computing*, Nottingham, UK, pp. 54-69.

[23] L. Takayama, L. Leung, X. Jiang, and J. Hong, You're Getting Warmer! How Proximity Information Affects Search Behavior in Physical Spaces. In *Extended Abstracts of the Human Factors in Computing Systems: CHI2003*, April 5-10.

[24] J. Goodman, S. Brewster, and P. Gray, P., Using Field Experiments to Evaluate Mobile Guides, in Schmidt-Belz, B. and Cheverst, K., (eds.), *Proceedings of HCI in Mobile Guides*, workshop at Mobile HCI 2004, Glasgow, UK, Sep 2004.

[25] D.A. Kenny, D. Kashy and N. Bolger, Data analysis in social psychology, in D. Gilbert, S. Fiske, & G. Lindzey (eds.) *Handbook of Social Psychology*, vol. 1, Boston: McGraw-Hill, 1998, pp. 233-265.

[26] J. Cohen, Weighted kappa: Nominal scale agreement with provision for scaled disagreement or partial credit. *Psychological Bulletin* **70** (1968), 213--220.

[27] D. Sperber and D. Wilson. *Relevance: Communication and cognition*, Blackwell, Oxford, 1986