GPS Impact on Performance, Response Time and Communication – A Review of Three Studies

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ABSTRACT

This paper describes the basic work performance analysis from three research projects with a goal to investigate the impact of a decision support system that presents global positioning system (GPS) information to the decision makers in crisis management organizations. The goal was to compare the performance between teams that had access to GPS information in the command post with teams that had access only to paper maps. The method used was controlled experiments with the C3Fire micro-world. A total of 304 participants, forming 48 teams, participated in the three studies. The participants came from three different groups, university students, municipal crisis management organizations and rescue service personnel. The result shows that the performance and communication change depending on if the teams used GPS support or paper maps. The result also shows that the participants' background and perceived complexity of the task have an impact on the results.

Keywords

Crisis management, decision support, global positioning system.

INTRODUCTION

This review paper compares the results from three research projects, all with the goal to study how a decision support system affects the work in a crisis situation. All three projects had the same experimental approach and studied the crisis management work of three different groups of participants; university students, municipal crisis management organizations and rescue service personnel.

304 participants took part in the three studies. In the first study, conducted 2006, the research was tested on non-professional participants, 132 students formed 22 groups (Johansson et al 2007; 2010). In the second study, conducted 2008-2009, the participants were professionals belonging to different municipal crisis management organizations, including both rescue service personnel and other municipal employees. 108 professionals formed 18 teams (Granlund et al, 2010; 2011a; 2011b). In the third study, conducted 2010-2011, a total of 64 professionals formed 8 rescue service teams.

The organizations of interest were Swedish municipal crisis management organizations and their crisis management teams. The goal was to understand differences in the collaboration and work processes of teams that had access to GPS information in their digital map systems at command center and command post level, compared to teams that had only paper maps in the command posts.

The participating professionals belonged to different municipalities in Sweden. Currently, many of these have made, or are about to make, investments in information and communication technologies, that gives the decision makers in the command centers and command posts access to GPS information. All this is done in order to enhance performance and control of the work.

GPS and digital maps are seen as support tools for crisis management. Management is understood to be more efficient with the introduction of these new technical supports. The reality is that the tools distribute large amount of information automatically to the decision makers. All users at all levels of management have in many

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situations access to the same information simultaneously. What was originally seen as an aid in the management work can have unsuspected consequences. The tools change the requirements for leading and organizing emergency efforts. The objective of the paper is to find indications on what has changed with regards to performance, response time and communication volume.

EXPERIMENT DESIGNS

The method used for the three studies was controlled experiments with the micro-world simulation C3Fire (www.c3fire.org; Granlund, 2001; 2003). The system generates a dynamic forest fire fighting task with characteristics similar to those people normally encounter in real-life situations. The system automatically logs all actions taking part in the simulation. It allows for controlled studies of collaboration, decision-making, cultural differences in teamwork and effects concerning information communication tools in command and control environments (Smith et al., 2008; Lindgren et al., 2006; Johansson et al., 2003; 2005; Foltz et al., 2008; Tremblay et al. 2008; Artman et al., 1998).

Two different designs

The experiment design for Study 1 and Study 2 was identical. For the third study the original design was amended with to the aim of increasing complexity and respond to rescue service professionals training needs.

Design in Study 1 (Students), and Study 2 (Municipal Crises Management)

Study 1 and Study 2 had the same between-group design with one factor: (a) crisis management teams using GPS, and (b) crisis management teams using paper maps (Figure 1 and 2).

In each group, three participants worked as command centre (CC) with one commanding officer and two liaison officers. Three participants worked as ground chiefs (GC). The CC had no direct contact with the simulation and controlled the simulated world indirect via the GC. The GC directly controlled three units (fire brigades) each in the simulation, a total of nine units.

The difference between the two conditions was the *complexity* of the type of support the commanding officer obtained, in terms of GPS with access to exact positioning of the resources in the simulated world, or a paper map without any automatic information.

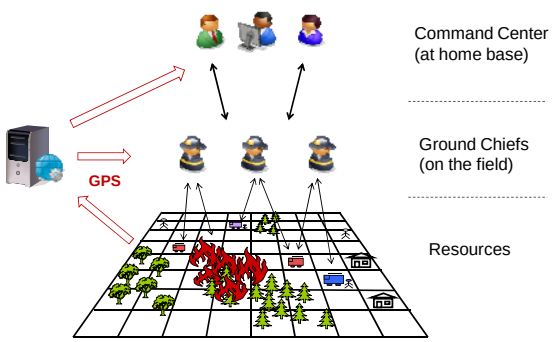

Figure 1. Design Study 1 and 2, GPS condition.

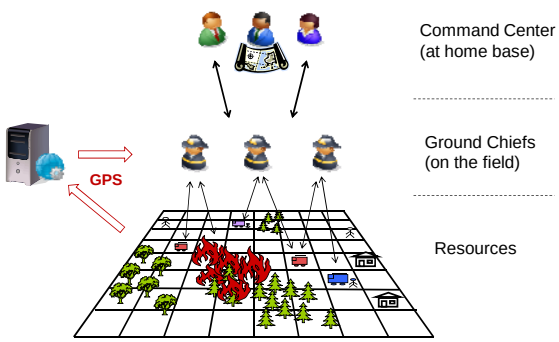

Figure 2. Design Study 1 and 2, Paper Map condition.

The experiment *procedure* included a customary training, then five regular simulation cycles. Each cycle include a 20 min simulation trial, 5 min of reflective questionnaires and 20 min of joint reflection, and after action review, where the group sees a fast recording of their actions during the simulation trial.

Design in Study 3 (Rescue Service Personnel)

The goal of the design in Study 3 was to increase the complexity and respond to rescue service professionals training needs. The development of the new design was interactive, done in collaboration with three different rescue services. The rescue services requested: (1) an additional level of command, (2) more personnel involved in the simulation, (3) more *complexity for the simulated task*, (4) more *complex scenario*, (5) longer simulations and (6) slower tempo.

Study 3 has the same between-group design with one factor as Study 1 and Study 2: (a) crisis management teams using GPS, and (b) crisis management teams using paper maps. The differences between the designs are in the six points requested by the three rescue services.

(1) The organization of the participant group has four levels of command instead of three; command center (CC) at home base, command post (CP) on the field, and four ground chiefs (GC) directing units in the simulation (Figure 3 and 4) (2) Each group has eight participants. (3) The resources in the simulated world is, 10 firefighters, 5 water logistic trucks that supply water to the fire fighters, 3 excavators for digging firebreaks and 3 units for evacuate citizens, 1 unit for the CP reconnaissance purposes. (4) None of the resources are linked to any of the ground chiefs. A structure for who is using which resources and when must be set up by the team. The complexity of the task to distinguish the fire is increased. Also, the ability to communicate is set free. Everyone can email everyone. This forces the team to form a structure for who is allowed to communicate to who and in what manner. (5) The simulation time have been doubled to 40 minutes, but the whole training day has been reduced to one full training sessions and three full simulation cycles. (6) The fire spread with a slower rate and the firefighting units move slower.

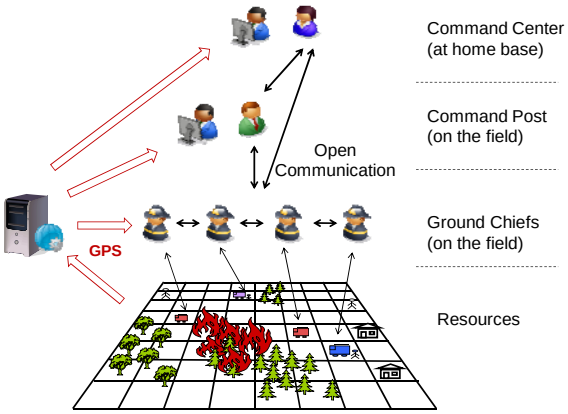

Figure 3. Design Study 3, GPS condition.

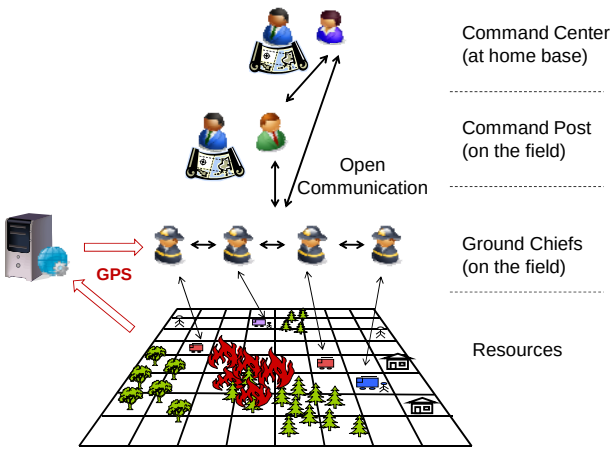

Figure 4. Design Study 3, Paper Map condition.

The experiment *procedure* included a customary training, then three regular simulation cycles. Each cycle include a 40 min simulation trial, 5 min of reflective questionnaires and 20 min of after action review.

RESULTS

The results from the three studies are presented with respect to the two conditions GPS and Paper Map and with regards to performance, response time and communication volume.

Performance

The main task and goal for the crisis management teams is to stop the forest fire and save houses. The performance of the team is measured by the total amount of burned down area at the end of each simulation. The performance measure gives an overview of the difference in the mean between the different types of teams during their five simulation trials. A small amount of burned out area is preferable to a large. The measure, however, says nothing about the type of surface, forest, field or house, which has been burning.

For *Study 1* the results showed no significant difference between GPS and Paper Map in the fifth and most important simulation trial. The mean values imply that groups with a GPS support had a better performance than those who used Paper Maps (Figure 5).

For *Study 2* there is no over all performance difference between GPS and Paper Map in the five simulation trials and the trend of teams with GPS to have a smaller amount of burnt out area is definitely broken in simulation trial 5. The professionals have an inconsistent result compared to Study 1 (Figure 6).

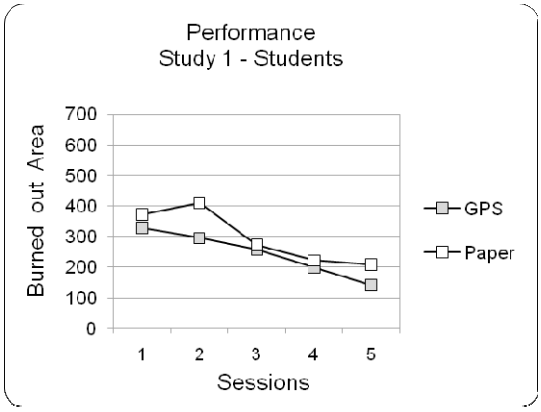

Figure 5. Performance for the students, Study 1

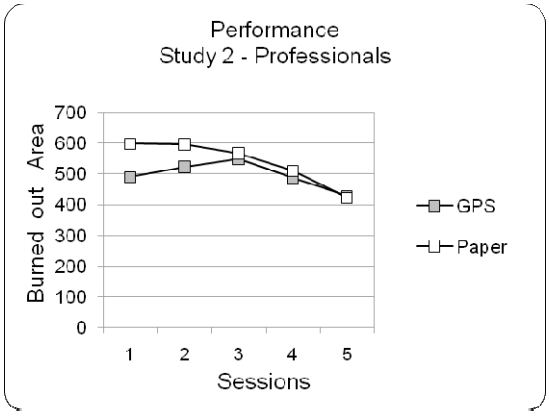

Figure 6. Performance for professionals, Study 2

One explanation for the results is that the CC of the participating groups is not uniform but has various compositions. The total result is divided into the subgroups RSCC and MCC for each condition. Subgroups where the team CC consist solely of rescue personnel is called RSCC, and subgroups where the team CC consist of a mix of other municipal personnel and rescue personnel is called MCC. The RSCC consists of a homogeneous set of personnel, almost exclusively men, with joint training and experience, and with a professional experience in managing crisis events. MCC consists of a diverse group with a variety of training and professional experience, where one fraction of the participants is used to manage crisis events, while the other is familiar with management under normal conditions. The result shows that RSCC follow the trend as expected from Study 1 the RSCC GPS teams perform better than RSCC Paper Map teams (Figure 7). MCC does not follow the trend from Study 1, that is, the MCC GPS teams do not perform better than MCC Paper Map teams (Figure 8).

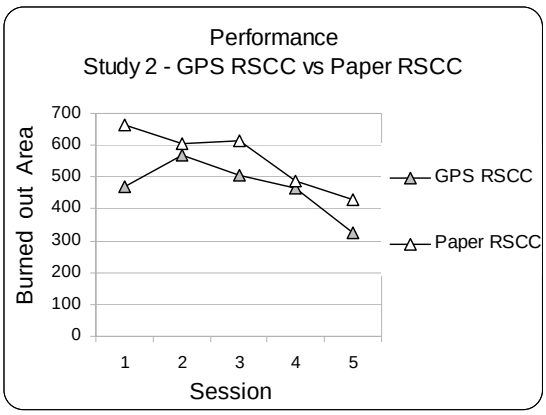

Figure 7. Performance for professionals, Study 2

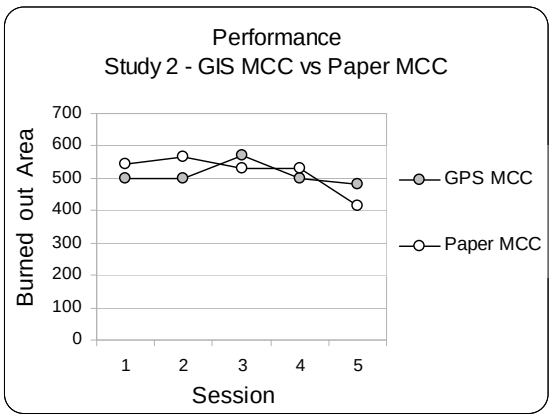

Figure 8. Performance for professionals, Study 2

The difference in performance between RSCC and MCC teams using GPS are in the fifth simulation trial significant. RSCC teams perform significantly better, $t(6) = 4.20$, $p = .006$, than MCC teams (Figure 9). RSCC and MCC teams using Paper Maps show no difference in the fifth and most important simulation trial. Their average result is intermediate, better than GPS MCC teams, and worse than GPS RSCC teams (Figure 10).

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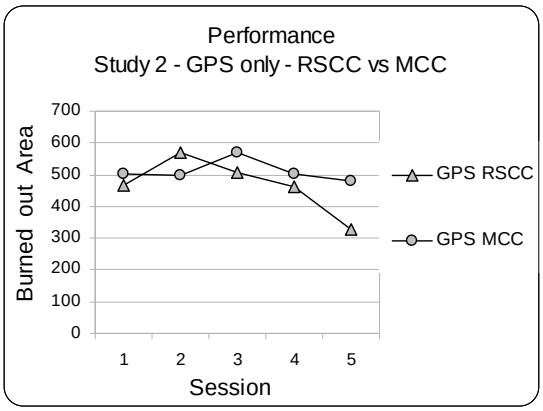

Figure 9. Performance for professionals, Study 2

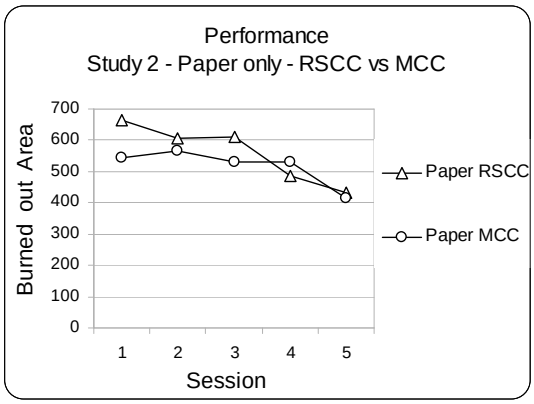

Figure 10 Performance for professionals, Study 2

For *Study 3* the design of the study is different. Only three simulation trials can be used for performance calculations. This is a difference from Study 1 and Study 2 where five trials where used. The result shows that there is a significant performance difference between GPS and Paper Map in the third and most important simulation trial. Teams using Paper Maps perform significantly better, $t(4) = 3.05$, $p = .038$ (Figure 11). This is clearly different from the performance result in Study1 and for RSCC teams in Study 2.

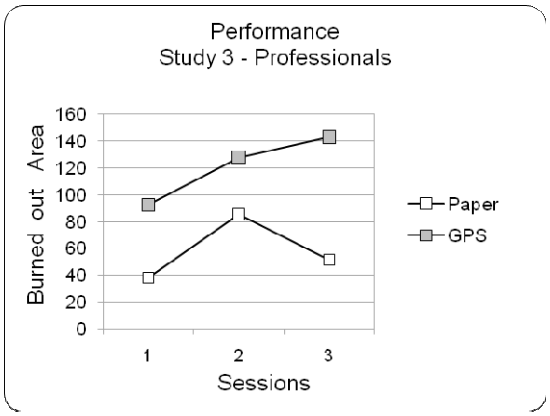

Figure 11. Performance for professionals, Study 3

Response time

In emergency response the time from alarm to first response is important. The measure of response time is the time, in seconds, between when a unit detects a fire to the moment when a unit has closed out the fire in some part of that area.

For *Study 1* the results showed no significant difference between GPS and Paper Map for response time. The mean values show that GCs in the different conditions have similar response time (Figure 12).

For *Study 2* the results showed no significant difference between GPS and Paper Map conditions. The mean values imply that GCs in the different conditions have different trends in their respond time in the third last sessions (Figure 13).

For *Study 3* the results showed no significant difference between GPS and Paper Map conditions. The mean values imply that groups with a GPS support had a longer response time than those who used Paper Maps (Figure 14).

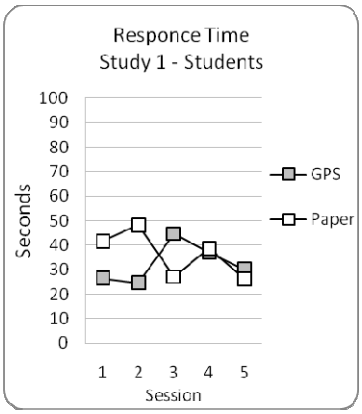

Figure 12. Response time for students, Study 1

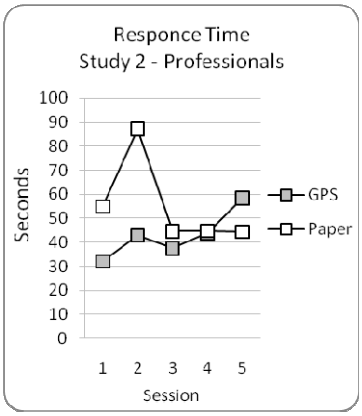

Figure 13. Response time for professionals, Study 2

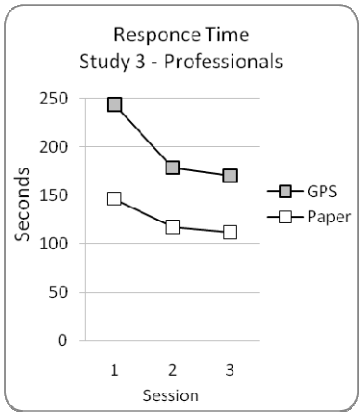

Figure 14. Response time for professionals, Study 3

Communication Volume

The volume of communication is presented as amount of send messages from respectively CC, CP or GC. It gives an overview of the difference in the mean between the different entities within the teams, but it says nothing about the content or length of the send messages.

For *Study 1* the results show the communication volume for CCs and GCs in the GPS and Paper Map condition. In the fifth simulation trial GCs in the Paper Map condition send significantly, more text messages than GCs in the GPS conditions (Figure 15).

For *Study 2* the results show that the communication volume for GCs in the Paper Map condition send significantly, $t(16) = 3.13$, $p = .006$, more text messages than GCs in the GPS conditions (Figure 16).

For *Study 3* the results again show similar patterns of communication volume for GCs in the GPS and Paper Map condition. GCs in the Paper Map condition send on an average more text messages than GCs in the GPS conditions, but the difference is not significant (Figure 14). (To simplify the comparison between Study 1, 2 and Study 3, have the amount of send messages in Study 3 been divided by two. Figure 17 shows the amount off messages send during a 20 minutes period.)

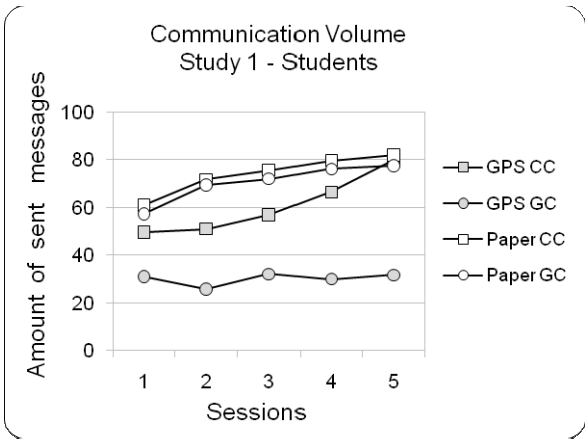

Figure 15. Communication Volume for students, Study 1

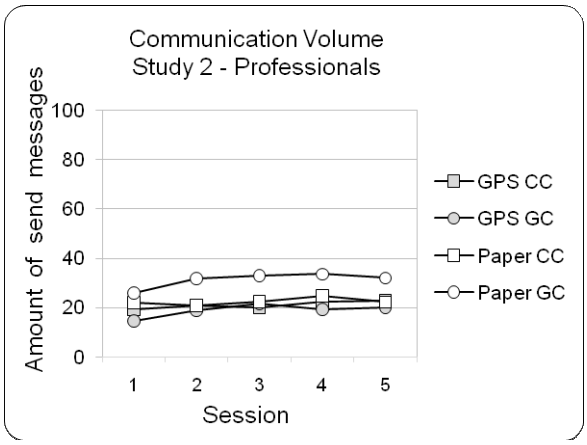

Figure 16. Communication Volume for professionals, Study 2

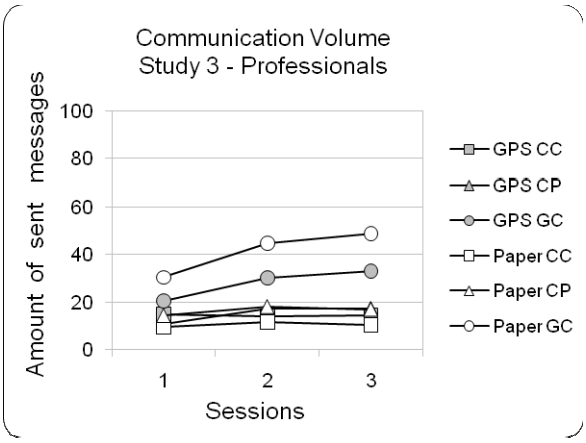

Figure 17. Communication Volume for professionals, Study 3

DISCUSSION

Performance, response time and communication volume will here be discussed in terms of complexity, efficiency and work distribution.

Performance

The performance of the various studies could be explained on the basis of the simulation exercises actual and perceived complexity. An observation when comparing the performance measure in results from Study 1 and Study 2 is that the students does perform better than the professionals independent on if they were using GPS or Paper Maps (Figure 5 and 6).

In *Study 1* the participants were relatively young and had no previous knowledge of crisis management but rigid experience of computer games. For them, the complexity of the game was low. They played the game C3Fire. They were most successful in the GPS condition, as expected. Observations from the experiments showed that the students saw the game as the problem they should handle. Win the game by putting out the fire on the shortest time possible was the goal.

In *Study 2* the participants recognized the simulations as training in crisis management or in communication, not as a computer game. Observations from the experiment were that the professional participants did perceive the sessions as more complex than the students in Study 1, although the simulation setting itself was not changed. The professionals, as well as the students, knew they were observed and analyzed in a research project. They behaved like professionals when they solved their problem. They used strategies from real life, like to discuss before they act, not using all the resources directly, etc. They saw the simulated event's resemblance to a real situation. They did not try to win the game as a game; they tried to do what they should have done in a real situation.

Extra complexity could also be found within and between the participants. The participants were a mix of professional staff who were active in the same municipality, but who had different *experiences* of management. The municipal employees were accustomed to management under normal circumstances, using democratic processes and consensus in their work. Rescue service personnel were used to management under extreme conditions. Their formal *education*s also vary. Municipal employees often had a thorough academic training while service personnel had regular training in methods for emergency management. The participant group's experiences and education increases the complexity in the micro world simulation. The task becomes more difficult to solve. Participants cannot, or do not want to, give up their methods and try to pursue them in the game. They tried to adapt the methods to each other and to the game.

In the *Paper Map* condition this was accomplishable for both RSCC teams and MCC teams. The information that the CC had about what was happening in the simulated world was always given by the GC. GC prioritized all information and conveyed only that which was important to the CC.

In the *GPS* condition the information given to the CC was automatic and unlimited and without being prioritized by GC. The RSCC teams, where the command center consists of rescue service personnel with joint training and experience, could overcome the complexity and take advantage of the GPS information. The MCC teams on the other hand could not benefit from the GPS. The mixed CC in these teams had an additional level of complexity to manage. Their staff had different experiences and management practices. They had to allocate time for methodological interactions and had less time to allocate for the classification of GPS information. Thus, they had the highest grade of complexity to deal with and the worst performance.

In *Study 3* the complexity in the simulation setting where increased. There were no predetermined structures for communication and resource allocation. The resources had additional functions. The task was expanded to involve third party considerations. On the other hand, in this study, all participants in the teams knew each other well. They had been active within the same rescue service. They had shared experiences, regulations and regular education in management practices. Their grade matched their assignment in the simulations command structure. The complexity was increased in the simulation setting and lowered with regards to participant interaction.

The result though was opposite to the expected. Teams with *GPS* did not perform best. The common emergency management methods and the information automation did not give the expected advantage. The teams within the Paper Map condition performed better. A reason for this could once again depend on *complexity*. The automatic information was given to both CC and CP without prior classification as important or unimportant. This classification is in real life normally done by ground chiefs in the field. The teams in the GPS condition had to allocate time to handle the information. Teams using GPS did not have time to adjust their ordinary management methods, basically adapted to paper maps, to the situation with GPS information. Their amount of burned out area was in the last simulation trial still increasing. That is a sign of the three simulation trials not being enough for learning to handle the complexity of the GPS setting.

The CC and CP in teams in the *Paper Map* condition had a situation that in much resembled what rescue service commanders experience in reality. The grade of complexity was lower and better adjusted to their ordinary methods. The commanders did not have to refine or alter their known methods too much, thus they performed better.

Response time

The measurement on the time from alarm to that the first response activities has started indicates the behavior learned by the GC and perceived as *effective* by the team. They could act directly or wait for order from the commander. The discussion on response time is based on the result presented above and observations made during the exercises. Further analyses are needed to establish the different teams exact response pattern.

For *Study 1* the mean values imply that groups in both GPS and Paper Map condition from first simulation trial to the last have the same response time, that is, they have the same routine throughout the whole exercise. No learning, no change and adjustments of response methods, depending on the decision support, are accomplished within the team. The students already pretty much from beginning knew what to do when they found fire, which is start extinguish immediately (detect fire – act – inform CC).

For *Study 2* the results showed that the GC in the two different conditions has different ideas on how to respond. GC in the *Paper Map* condition have after the third trial learned a routine for response and they thereafter perform the same routine with the same speed every time (detect fire– act– inform CC). The *efficiency* of the first response depends on the actions of the GC. The result also shows that the teams that have *GPS* do not initiate first response according to a predetermined routine. They await orders from the commander (detect fire - inform CC – act/await order). This is an indication that the decision making process is altered by the GPS. The first respond decisions are in the last trial no longer made by the GC they are passed over to the commander, an inappropriate first response routine has been developed by the teams. The time to first response is still raising, this is a sign of that the CC is still adjusting the response method. The *efficiency* of the first response depends on the actions of the CC.

For *Study 3* the results again show that the GC in the two different conditions has adapted a routine on how to respond and that the routine differs depending on condition. The GC in the *Paper Map* condition has learned to inform their CP before responding (detect fire– inform the CP – act). The *efficiency* of the first response depends on the actions of the GC. The GC in the *GPS* condition does not initiate first response. They await orders from the commander (detect fire - inform the CP – await order). The first respond decisions are made by the CP. The *efficiency* of the first response depends on the actions of the CP.

Communication Volume

The result of the communication volume shows a consistent result where the CC and CP in each study sends as many messages regardless of whether they have GPS support or not. GC however, sends more messages in the Paper Map condition than in the GPS condition. The majority of GC messages in the Paper Map condition contain sorted and prioritized information about the fire and activities. The GC in the Paper Map condition performs part of the work that the CC in the GPS condition do.

It is also interesting to note that the CC in Study 2 sends relatively fewer messages, than the CC in Study 1. The professional participants bring with them experience and knowledge about crisis management methods and they act accordingly during exercise. The students in Study 1 have no such experience or knowledge and have no inhibitions against talking. The students were also selected as volunteers and are likely the most extrovert partition of university students in general. The professionals were chosen because of their ability as crisis managers, being extrovert is far from a required feature in times of crises.

CONCLUSION

The initial objective of this paper was to try to resolve how GPS support could affect performance, response time and communication in crisis management teams. The result shows that the participants' background and perceived complexity of the task have an impact on the results. To summarize the findings following conclusions can be drawn.

- GPS affect *performance*. The performance increases for the teams whose CC has time to evaluate the automated information and to adapt their methods to it. The performance is reduced for the teams that did not have time to learn to deal with the complexity and learn proper collaboration methods.
- GPS affect *response time*. GPS teams with professional participants have longer response time than teams without GPS. It seems as the decisions are moved to a higher level in the command chain. Even ordinary first response decisions with a short time span.
- GPS affect *communication volume*. All three studies indicate that the GC in GPS sends fewer messages than in the GC in Paper Map. The GC in the GPS condition does not support their staff in the same way as in the Paper Map condition. GC in the GPS condition relies on information about events in the simulation to be mediated by the GPS technology and on their CC to have the ability to sort and prioritize all information.

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