There's no 'I' in 'Emergency Management Team:' Designing and evaluating a serious game for training emergency managers in group decision making skills

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ABSTRACT

Serious games are games that are designed to educate rather than entertain. The game outlined and evaluated here was commissioned and designed as a tool to improve the group decision making skills of people who manage real-world emergencies such as floods, fires, volcanoes and chemical spills. The game design exploits research on decision making groups and applies pedagogically sound games design principles. An evaluation of the game design was carried out based on a paper prototype. Eight participants were recruited and assigned to two groups of four participants each. These groups were video recorded while playing the game and the video was analysed in terms of game actions and member participation. Results indicate that the group who behaved in a more appropriate manner for a decision making group were rewarded with more positive feedback from the game state. These findings suggest that the game itself delivers appropriate feedback to players on their collaborative behaviour and is thus fit for the purposes intended in the current project.

General Terms

Management, Measurement, Design, Experimentation

Keywords

Game & Simulation Design; Serious Games; Learning Evaluation; User studies and evaluation.

1. INTRODUCTION

Emergencies constitute unpredictable, stressful environments that are managed by groups of people drawn from a variety of disciplines and agencies that may or may not have regular contact with each other. The process of managing an emergency requires both knowledge of pre-defined plans and procedures and an ability to communicate effectively and engage in collaborative decision making in order to solve the problems presented by the event [1]. Thus, appropriate training in both procedural knowledge and group decision making skills are essential in any emergency response plan [2]. The current project aims to train emergency managers in appropriate group decision making behaviour.

Programs designed to train emergency managers should ideally expose participants to exactly the sorts of stressful, uncertain and dynamically changing environments that they are likely to encounter in the event of a real emergency [3]. Thankfully, these events do not occur with regular enough frequency for hands-on training to form any significant part of an emergency management course. Rather, training is often conducted either through real-world simulation, classroom role-playing, or a combination of both [4, 5]. There are advantages and disadvantages to both forms of training. For example, while live action real-world simulations are highly engaging and require emergency managers to perform precisely the tasks they would in a real emergency, they are expensive in terms of both money and manpower, take months to plan, and consequently cannot be performed with any great regularity. Classroom role-playing is relatively inexpensive, but does not engender the same level of engagement and stress that would constitute a real emergency.

Computer game technology appears to represent an ideal tool for conducting emergency management training, as it is relatively inexpensive and allows for the real-time presentation and controlling of complex, engaging and dynamically changing environments [5]. However, in designing a computer game based training tool, it is essential to incorporate "sound cognitive, learning, and pedagogical principles into their design and structure." [6]

The current paper presents work being conducted as part of an EU LEONARDO project named DREAD-ED, which aims to utilize computer game technology in the training of emergency management personnel (see http://www.dread-ed.eu for further information). The problems commonly encountered by decision making groups, suggestions from the literature on how these problems can be overcome, and pedagogically sound methodologies for designing educational computer games are presented below, followed by the design and evaluation of a game for training group decision making skills. Finally, some conclusions based on the research are presented, along with implications for future work.

2. DECISION-MAKING GROUPS

2.1 Background

Decision making groups are formed on the expectation that decisions made by the group as a whole should be better informed, more considered and ultimately more successful than decisions made by any individual member of that group. However, the consistent finding across decades of research is that groups usually fall short of this expectation [7]. Few studies have reported that groups have performed as well as their highest performing member would have individually, and fewer studies still have reported group performance that is better than the performance of any individual efforts [7]. Kerr and Tindale [7] have identified a number of factors that lead to the poor performance typically observed in decision making groups, and recommendations have been made on how best to

avoid these. A brief synopsis of these factors and recommendations are outlined below.

2.2 Motivation

The motivation of group members has been identified by a number of researchers as essential to the successful working of a group. Specifically, researchers discuss the problem of 'social loafing,' whereby people reduce their work output when working in a group context due to reduced risks of evaluation, opportunities to free ride on other group members' efforts, and an unwillingness to do the work that a capable, free-riding partner could be doing [8]. A number of factors have been identified that can attenuate the social loafing effect. For example, high group cohesion [9] and anticipated punishment for poor performance [10] have both been found to reduce the social loafing effect. Setting challenging goals and basing the entire groups' outcome on the performance of its weakest member have also been found to attenuate the social loafing effect [7]. Of particular significance for the task of managing emergency situations, the importance of the task at hand can also cancel out social loafing effects. A very important task can actually lead to capable group members increasing their efforts on collective tasks in order to compensate for the anticipated poor performance of the other group members [11]. However, this effect should not be relied upon as the basis of an emergency response plan.

2.3 Stress

Stress and time pressure have been identified as a factor in explaining the poor performance of decision making groups [12]. Stress tends to narrow attention onto more vital task features, and to prompt more simplified, heuristic information processing [13]. Stress can also lead to greater uniformity and greater influence from dominant members [7]. Under stressful circumstances, once a dominant opinion has been expressed, the tendency is to agree with it. Interestingly, it appears that having a process in place to deal with the management of emergencies should keep stress at moderate (i.e. ideal) levels. A group who has received training in sound decision making processes will be aware of time pressure, but not feel that it is unmanageable due to the training in sound decision making processes. The process should lead the time pressure to cause focus and productivity rather than stress. Indeed, Kelly [14] suggests that you can train groups' pace and quality of work, and they will then work at this pace under stressful conditions.

2.4 Information Processing

A number of researchers have examined group information processing in explaining the underachievement of decision making groups. Stasser and Titus [15] suggest that groups are less-than-optimal users of information and often ignore information that is not widely shared among members. This can lead to problems when each member of the group possesses unique information that must be shared in order for the group to make an informed decision. Splitting the decision task into components; information search first, followed by integration and decision, helps to ensure that all the relevant information is aired and used in the group decision [16]. Assigning group members to be responsible for certain categories of information and making sure that knowledge of who knows what is shared among the group members has also improved performance [17]. It appears that a pre-planned structure within which to carry out the group decision making process is essential to successful group performance.

2.5 Groupthink

Groupthink [18] describes a situation where highly cohesive groups demonstrate a lack of critical inquiry and thus make poor decisions. Groups suffering from groupthink tend to reach a decision before realistically appraising the merits of all available courses of action. Groups that contain a minority of dominant members typically display the symptoms of groupthink [19] in that they suggest fewer solutions, use fewer outside sources of information, and use less information before a decision. Callaway et al. [19] and Janis [18] both place an emphasis on having specific procedures in place to prevent the effects of groupthink.

Common to all of the factors identified in explaining the under-achievement typically displayed by decision making groups is the insistence that it is vital for groups to be trained in a process for controlling group decision making behaviour. Indeed, group research strongly suggests that groups can benefit from reflecting on the process of their meeting, regardless of the specific process that they eventually follow [20]. Allowing groups to work unguided and without relevant training in appropriate processes can lead to social loafing, stress and a lack of sufficient information sampling. Appropriate training provides task experience [21], group experience [22] and improves a groups' ability to deal with stress. Having a structure in place to control the decision making ensures that group members contribute equally, communicate all necessary information to other group members and realistically appraise all courses of action before making a decision. The DREAD-ED game aims to fulfill all of these requirements.

3. DESIGNING PEDAGOGICALLY SOUND SERIOUS GAMES

Serious games are games that are designed to educate rather than entertain. Research has indicated that computer games can prove to be innovative and powerful tools for education [6]. Indeed, combining psychological research and games design principles offers a framework for developing educational games that promote learning while maintaining high motivation of the players [23]. If designed correctly, serious games can utilize the inherent motivation demonstrated by game players to teach skills that are of immediate practical benefit [6]. Unfortunately, a large number of educational, or serious, games appear to have ignored recommendations on game design, particularly in regard to two issues; embedding learning outcomes within the game mechanics, and providing immediate and specific feedback to participants regarding their behaviour.

Bogost [24] describes the process of embedding the learning outcomes of a serious game within the game play mechanics as constituting 'procedural rhetoric.' The author describes a number of serious games that are deficient in procedural rhetoric (p. 49-51). These games simply borrow the game play mechanics of traditional games and apply novel graphical skins to them. It is entirely possible to play these games successfully while remaining oblivious to the desired learning outcomes. The learning is not embedded within the game play mechanics, rather the player is presumed to infer the correct message from playing the game. Conversely, Bogost mentions a number of games, such as The McDonalds Videogame (p. 29) which excels in embedding the learning outcomes within the game mechanics, thus constituting superior tools for education. Habgood [25] investigated experimentally the importance of integrating learning content with the mechanics of a game. In two studies, the author found that a game in which learning was intrinsic to game play was motivationally and educationally more effective than an almost identical game in which learning was not intrinsic to game play.

The specificity of feedback provided by a manual or cognitive skills training program is a reliable predictor of future performance of those skills [26]. Feedback provided to participants by a game should be both immediate and specific to the actions taken [21]. Driving instruction courses provide a

good example of skills training methodologies. In these courses, the instructor examines the behavior of the learner as they drive and delivers timely and specific feedback concerning the proficiency of the learners' driving. Allowing a learner to drive for thirty minutes before producing a list of mistakes would not allow the learner to effectively discern which of the many actions taken were appropriate, and which were not.

Computer games motivate via fun, challenge and instant feedback within an environment that creates an immersive experience [6]. It appears that an effective serious game designed to teach group decision making skills to emergency management personnel should involve game-based problem-solving that delivers clear, timely and specific feedback to players. Such a game would provide both task experience and group experience to the decision making group. In order for this game to meet its training potential, it appears that the desired learning outcomes must be embedded within the game play mechanics. So, the game should encourage players to engage in the types of behaviours that characterise successful decision making groups; namely that group members contribute equally, communicate all necessary information to other group members and realistically appraise all courses of action before making a decision.

4. DREAD-ED GAMES DESIGN

A game design was created based on the requirements identified by the literature review. The game places players in a crisis management team that is dealing with an immediate and developing emergency. Each team member plays a role that has unique abilities within the game. The information that is needed to alleviate the negative effects of the emergency is distributed among all game players in the form of personnel. In order to successfully manage the situation, these personnel must be managed between group members and all players must effectively communicate their unique information to the other players and appraise the many courses of action available before making decisions.

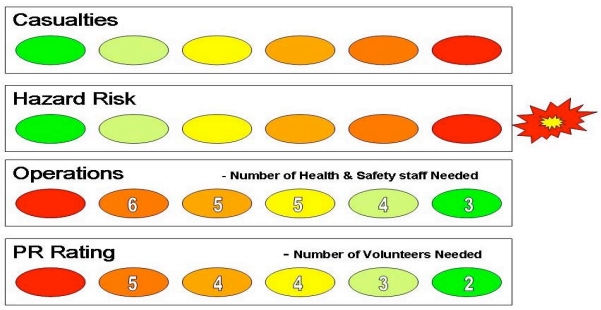

Figure 1. A graphic illustration of the scales used in a table top prototype to represent the game state.

The challenge presented by the game lies in managing the dynamically changing game state, which is represented by four six-point scales. Each scale represents an individual aspect of the emergency that can vary from 'perfect' to 'disaster' depending on game events and the performance of the emergency management team. Figure 1 presents a graphic illustration of the scales used in a table top prototype to represent the game state. The 'casualties' scale is the most important of the four scales in terms of evaluating team performance. If the casualty scale reaches its maximum, the team has lost the game. Conversely, if the management team ensures that the 'casualties' parameter does not increase, then they have completed the task successfully.

Importantly, 'injects' of information that alter the game state in an unpredictable fashion are introduced at specific points in order to model the dynamically changing nature of an emergency situation. This feature is designed to force players to plan in advance for unforeseen circumstances, as well as dealing with issues of immediate importance.

The game mechanic is based on assembling and deploying teams of similar personnel out of the nine available personnel classes in order to affect the values displayed on the game state scales. Each personnel class has a unique effect upon the game state when deployed. In addition, each character has unique abilities that interact with some personnel classes when deploying teams to deal with problems. A high-achieving group will excel at getting the right personnel to the right players at the right time in order to control the emergency. Importantly, a mechanism was developed that limits the number of actions per round available to the group. This mechanic, coupled with the limited time available for discussion and collaboration, was designed to create a stressful decision making environment.

The game has been carefully designed to deliver timely and appropriate feedback to game players on their group decision making behaviors. Specifically, the game presents an environment where it is advantageous to engage in the appropriate group decision making and communication behaviors. Groups that do not work collaboratively to solve the problems presented in the game should perform poorly. Thus, the learning is embedded within the game play mechanics and the game state itself should provide feedback on how well the group is performing in terms of soft skills.

In addition to the ongoing feedback delivered by the game state, the game has been structured to work in rounds, where natural breaks in game play allow a tutor to provide more detailed feedback to players. There are three stages to each game session. Initially, conditions are set by the particular scenario chosen for the training session. Game play is organized into a series of timed rounds, each separated by a phase in which a tutor has the opportunity to give feedback to players. The first timed round is assigned four minutes for discussion and each successive round is assigned twenty seconds less for discussion than the previous round. Once the full number of timed rounds has elapsed, an in-depth evaluation phase is initiated between the tutor and the participants.

5. EVALUATION OF THE PROTOTYPE GAME DESIGN

In order to evaluate whether the game design successfully fulfilled the requirements identified in the group decision making literature, a paper prototype was created using cards and a game board. The construction of a paper prototype allows for the careful examination of game mechanics without the development costs associated with an electronic version. The analysis was focused on determining whether groups that performed well at playing the game were also the groups that displayed appropriate group decision making behaviours. Specifically, it was intended that groups who performed well at the game should have relatively equal participation. Conversely, if a group contains members that either dominate or do not engage with the game and still perform well, the game design has not fulfilled the purposes intended.

In developing a method of evaluating whether or not the specified learning outcomes were met, it was a sub-goal to use strictly quantitative techniques that could be automated in the final electronic version of the game. The literature on group decision support technology appears to concern itself with the

quantitative measurement of precisely the behaviours of concern to the current project [20]. Relevant dependent measures identified in the literature include equality of participation [20, 27], absolute amount of interaction [28], overlapping speaking time [29], and speech segment length [29]. Thus, the following research questions have been developed: Do groups who finish the game with a higher game score also display a) more equal participation, b) a higher absolute amount of participation, c) less overlapping conversations, and d) lower mean length of vocalisation than groups who finish the game with a lower game score?

Figure 2. Participants playing the paper prototype

In order to test the questions identified above, eight participants were recruited (3 male, 5 female) from a sample of convenience and each paid £10 upon the completion of the task. Participants were divided into two groups of four players each. The game rules were initially explained to participants by a researcher via written instructions that were read aloud while making reference to the cards and game boards on the table. This was followed by a practice game round, in which all three game mechanics were demonstrated and the functions of different role and personnel cards were explained. Once participants had indicated that they fully understood the game rules, the first game round was initiated.

The game board was initially set to values that were common among all four groups. Each player was assigned one character role at random and all players were dealt six cards from the pool of personnel cards. The order in which personnel cards were dealt was controlled, so that both groups received the same cards. In addition, the order in which event 'inject' cards were arranged was constant across both groups. Both groups started with the same initial game state and cards that were subsequently drawn across the course of the game sessions (both personnel cards and event cards) were also identical in order. Thus, the better performance of one group over another group could only be attributable to a better use of the resources available.

While the final version of the computer game is designed to be played in the presence of a tutor who provides regular and specific feedback to players, the current evaluation is not concerned with evaluating the role of the tutor. Rather, the current evaluation seeks purely to establish whether the game represents a valid model of a dynamically changing decision-making environment (i.e., whether the game presents an environment in which it is advantageous to engage in appropriate decision making behaviours). As the presence of a tutor would necessarily direct behaviour towards that which has been defined as appropriate, the role of tutor has been omitted form this evaluation. Instead, the breaks between game rounds were simply used to re-set the necessary game parameters before starting the following round.

Data was captured through the video recording of participants while they played the game, using a standard digital camcorder and tripod. Video files were then analysed manually by an observer in order to extract the necessary data. Initially, the video for each group was viewed carefully and all game events, including changes in game state, deployment of teams, exchanging of personnel, and injects of events were noted, along with the time that they occurred. Subsequently, video files were split into ten intervals, each corresponding to one game turn. For the purposes of coding participant's behaviour, each of these video clips was divided into 500ms segments. A researcher worked through these video clips carefully and noted whether each player was speaking during each 500ms segment. In this way, a log of player communication and participation activity was created for both groups. It must be noted that a recognised system for coding semantic or linguistic properties of player interactions was not adopted, as this was not necessary in order to answer the particular research questions asked in the current study.

6. RESULTS

6.1 Game Success

The analysis presented here is based purely on group data and concentrates on the interaction of players within the group. It was not necessary within the framework of the current paper to analyse data in terms of individual players, so this was not carried out. Groups were analysed separately and results for both groups were compared. The first step in evaluating the game design was to identify whether one group performed better than the other. Table 1 presents three metrics that have been chosen to evaluate each team's success in dealing with the problems presented by the game.

Table 1. Results for Groups 1 and 2 in terms of three metrics of game success.

	Group 1	Group 2
Total increase in casualties	3	3
Number of teams deployed	8	10
Total hazard points reduced	9	11

The 'casualties' parameter was the ultimate barometer of success within the game. Increases in casualties occurred as a result of teams not dealing appropriately with the challenges presented by the game (usually through increases in the hazard risk parameter). As presented in Table 1, both Group 1 and Group 2 performed similarly in terms of the 'casualties' parameter. As such, it may not be appropriate to classify one group as a high achieving group and the other as a low achieving group. However, Table 1 also indicates that Group 2 deployed more teams and reduced the hazard risk by more points in total than Group 1. Thus, it appears that Group 2 was more effective at using the resources available within the game.

The remainder of this section is carried out under the premise that Group 2 is a high achieving group, while Group 1 is a low achieving group. While this premise is rather tenuous, it provides a useful structure to the comparison of groups in terms of member participation. As outlined in the method section above, a video recording of participants playing the paper prototype was divided into ten intervals that corresponded to the ten timed game rounds. Each round was broken into

500ms blocks, in each of which an observer noted whether each player was speaking or not. This produced a log of each player's participation over the course of an entire game session. These data were then analysed in a number of different ways in order to answer each of the identified research questions.

6.2 Equality of Participation

The first question concerned whether groups who finished the game with a higher game score also displayed more equality in participation among their members. In order to answer this question, the total number of 500ms blocks in which each participant was speaking in each round was summed. This produced a raw score for each participant for each round. However, because rounds decreased in duration as the game progressed, scores for participation necessarily decreased over successive game rounds. This had the effect of results from earlier rounds having more influence on the final figures than results from later rounds. In order to solve this problem, each participant's raw score for a round was expressed as a percentage of the total speech produced in that round by that group. This produced a picture of how engaged each team member was in each round of the game. As these data are difficult to represent graphically, a further transformation was conducted, where the mean percentage contribution for each participant across all rounds was calculated. These data are presented in Figure 3.

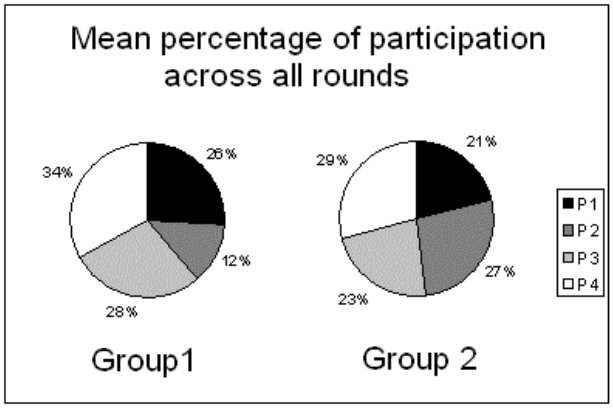

Figure 3. Mean percentage contribution for each participant across all rounds

Figure 3 suggests that participation was more equally distributed across group members in Group 2 than in Group 1. Specifically, in Group 1, Participant 2 only contributed 12% of total observed 500ms blocks containing speech, whereas Participant 4 contributed 34% of observed speech segments. In contrast, all members of Group 2 contributed to discussions within the range of 20-30%. Thus, the current analysis suggests that the group that performed more successfully at the game was also the group in which participants contributed more equally to discussions.

6.3 Amount of Participation

The second question concerned whether groups who finished the game with a higher game score also displayed a higher absolute amount of participation from group members. In order to answer this question, the number of 500ms blocks in which each participant was observed as speaking in each round was expressed as a percentage of the total time available in that round. This produced a picture of how much of the available time each participant spent speaking in each round. Subsequently, the mean percentage contribution for each participant across all rounds was calculated and is presented in Table 2. It appears that each participant on average in Group 2 spent 29.3% of the available time speaking, while participants in Group 1 spent 27.1%. Thus, the group that performed better at the game also spent more time in total participating in discussions. However, it must be noted that the difference between the two groups is very small.

Table 2. Mean percentage of total available time spent talking across both groups

	Group 1	Group 2
Mean percentage of total available time spent talking	27.1154% (SD 9.3)	29.3703% (SD 4.5)

6.4 Overlapping Speech

The third question concerned whether groups who finished the game with a higher game score also displayed less overlapping conversations than groups that finished the game with lower game scores. In order to answer this question, the number of 500ms blocks in which there were 2 or more people speaking was expressed as a percentage of the total time available in each round. A mean was then calculated for the percentages observed across all rounds. This data is presented in Table 3. It appears that in Group 1 two or more participants were speaking at the same time during 18.9% of all segments, while the figure was 28.3% for Group 2. Thus, contrary to our assumptions, the group who performed better at the game actually spent more time speaking over each other than the other group.

Table 3: Mean overlapping vocalisations and mean length of vocalisations across both groups

	Group 1	Group 2
Mean overlapping vocalisations	18.83357% (SD 5.77)	28.34941% (SD 5.01)
Mean length of vocalisation	4.239581 (SD)	4.175187 (SD)

The fourth question concerned whether groups who finished the game with a higher game score also displayed a lower mean length of vocalisation than groups who gained a lower game score. In order to answer this question, the mean number of 500ms blocks in which speech was observed for each participant in each round was calculated. A mean was then calculated for the each group across all rounds. This data is presented in Table 3. It appears that the mean length of vocalisations was very similar across both groups.

The current analysis was carried out in order to evaluate whether the group that performed better at the game was also the group that displayed more appropriate group decision making processes. Results were mixed, in that the group who performed better in terms of game success also exhibited more equal participation of group members and more total time spent talking than the lower achieving group, as predicted. However, the lower achieving group spent less time talking over each other than the higher achieving group and produced a similar mean length of speech, which was contrary to predictions.

7. CONCLUSIONS AND FURTHER WORK

The game outlined and evaluated here was designed as part of a training program to improve the group decision

making skills of emergency managers. The design was informed by the literature on maximum performing decision making groups. In addition, recommendations on effective serious game design were adhered to. The evaluation itself was based on a paper prototype version of the game and was carried out using quantitative methods that can be easily implemented in the digital version of the game.

Results indicated that of the two groups evaluated, the group who performed better in terms of game success also exhibited more equal participation of group members and more total time spent talking than the lower achieving group. These findings suggest that the game itself delivers appropriate feedback to players on their collaborative behaviour. Specifically, the group who behaved in a more appropriate manner for a decision making group were rewarded with more positive feedback from the game state, which was the expressed intention of the game design.

It must be noted that the higher achieving group also spent more time talking over each other than the lower achieving group and produced a similar mean length of speech events. While these results are contrary to our predictions, the validity of these measures, particularly that of overlapping conversations, is less clear. For example, observation of the video of Group 2 indicates that there were frequently two concurrent conversations taking place. It is unclear whether this style of interaction contributes to successful decisions or not. Furthermore, the presence of overlapping conversations may actually represent a measure of interactivity within a group. Specifically, a high number of overlapping conversations may indicate that the main speaker or contributor to the group is changing often, which has been identified as an indicator of appropriate group behaviour [29].

It is also important to note that the two groups on which current study is based actually performed quite similarly in terms of game success. One group was marginally more efficient at using the resources given, and this was designated as the higher performing group. Perhaps groups that performed very differently from each other in terms of game success would display more divergent patterns of collaborative behaviour. This is an empirical matter and will be pursued as part of future work in the current project.

While the primary aim of this study was to evaluate whether the higher performing group exhibited more appropriate behaviour than the lower performing group, it must be remembered that the game will form part of a larger training program and that the ultimate aim of the entire project is to improve the decision making behaviour of groups. A vital part of that process is the inclusion of a tutor in sessions to monitor participants and shape appropriate behaviours in group members. The intention is to help all groups become groups that display the appropriate decision making processes when dealing with dynamically changing events under stressful circumstances.

The current analysis is based on a co-located paper prototype, while the aim of the project is to develop a distributed multiplayer computer game. There are well documented differences between face-to-face and computer mediated communication (CMC) and it may be necessary to tweak some aspects of the game design in order to reflect this when the digital version is completed. For example, CMC has been found to lead to more equal participation of group members, greater information sharing, less normative influence, and ultimately better decision making than face to face communicating groups [20, 29, 30]. However, there are also a number of disadvantages to CMC, including slower and asynchronous communication, decreased information flow and greater group conflict [20, 29, 30]. A major advantage of the computerised version of the game will be that the analyses conducted in the current study can be conducted in real-time and displayed to participants as they are playing. If incorporated successfully within the game design, this display may have the effect of shaping players behaviour (as seen in [20, 27, 28, 29]) and reducing the workload of the tutor.

In summary, the current study suggests that the game design is fit for the purposes intended in that it provides an engaging environment where participants must demonstrate the skills required in managing a real emergency in order to be successful at the game. In general, the group who behaved in a more appropriate manner for a decision making group were rewarded with more positive feedback from the game state.

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