Serious Gaming for User Centered Innovation and Adoption of Disaster Response Information Systems

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Abstract

Global profusion of information technology has spawned a large and varied number of tools and systems to aid disaster responders in managing disaster-related information. To adequately study the conception, development and deployment of such tools and systems, the user and the operational context in which user tasks are performed play a central role. As natural disasters however happen unexpectedly, often occur in remote areas and always impose working conditions of high time pressure and high situational volatility, user involvement is difficult to achieve for adequately studying tools and systems in disaster conditions. Current approaches for adoption in disaster conditions are therefore either resource intensive or lack realism, or both. In this paper we propose the use of serious games to balance the realism of a disaster situation with an efficient and effective study setup and execution. Building on existing literature for serious gaming, we present in this paper a serious game that focuses on the information management and decision making processes in an urban search and rescue setting. Through several game instances that have been played in the past three years, we examine the usefulness of serious games as a method to conduct research, to facilitate user centered development and to support dissemination activities.

Keywords: Serious Games, Information Management, Disaster Response, Impact Evaluation, User centered design, Innovation development, User adoption

1 Introduction

The importance of decision making and information management during crisis response and disaster management has been extensively studied (Comfort, Ko, & Zagorecki, 2004; Fiedrich, Gehbauer, & Rickers, 2000; Van de Walle & Turoff, 2008). While this importance has been established for quite some years, ongoing innovation and developments continue to present new opportunities for innovations to support disaster responders and crisis managers. Due to an ever more connected world, the development of mobile technology and technological advances in the field of computer science and software engineering, new opportunities for information gathering, analysis and dissemination continue to emerge. These innovations emerge through a three-step process of innovation: (1) conception: generating new ideas and possibilities for innovation, (2) development: maturing the innovation from the conception stage to a workable solution and (3) deployment: delivering the innovation to the end users (Pavitt, 2005).

Depending on the specific application, the resulting innovations aim to introduce an improvement in the field of information management, decision support or other disaster management processes. The specific aim or objective differs between innovations, for example new technology may be introduced to improve efficiency of an assessment process, or allow the affected population to communicate, so they can request and offer help to each other. While an innovation has often been designed with a specific aim in mind, the innovation in itself is not sufficient to reach that objective. In order to achieve the intended objectives and leverage the potential, innovations have to be adopted by the user (Damanpour, 1987). Adoption of an innovation, follows according to Rogers (2010) a 5-step process: (1) *knowledge*: the user is exposed to the innovation, (2) *persuasion*: the user's interest is piqued and actively searches out more information, (3) *decision*: the user weighs the advantages and disadvantages and reaches a decision about acceptance or rejection, (4) *implementation*, where the user actively deploys and employs an innovation while continuing to determine its usefulness and (5) *confirmation*: the user finalizes the decisions for continued use of the innovation.

The processes of innovation development and innovation adoption are not disconnected, and innovation processes are increasingly a collaborative effort between developers and (potential) users (Aldrich, 2003; Rogers, 2010). Research, amongst others by Abrahamson (1991), illustrates the importance of user involvement in the development of innovations to increase the likelihood of adoption. In these cases the adoption process does not start after the innovation process but happens simultaneously.

Combining the innovation development and user adoption processes, we can identify different possibilities for a connection between the innovation process and the user adoption stages. As shown in Figure 1, involving the user in the innovation development process can be realized through the organization of specific *user centered activities*. Depending on the specific stage in the innovation development and user adoption process, we can distinguish different types of activities that support collaboration and alignment between the two processes.

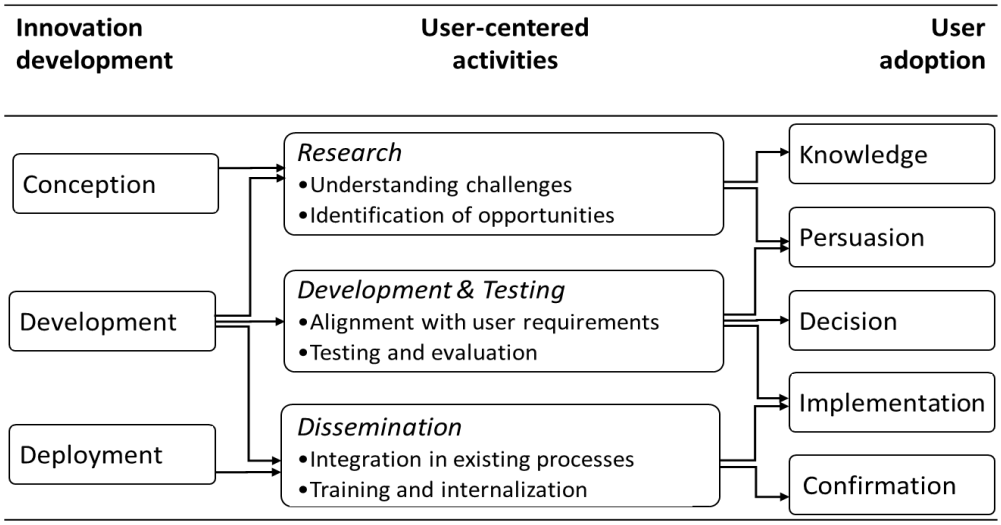

Figure 1 User centered activities in development and adoption process

As shown in Figure 1, we distinguish three different categories of activities: research, development and testing, and dissemination. *Research* activities play an important role in the conception stage: involving the user improves the understanding of the challenges and aid in the identification of new opportunities. Research activities also aid in exposing the user to new opportunities and providing more information to the user, thus supporting the knowledge and persuasion stage in the user adoption process. During *development and testing* the user can provide valuable feedback to the developers and alignment with the requirement can be ensured. These activities aid in providing information (persuasion), demonstrating the added value (decision) and testing the innovation in a context relevant to the user (implementation). In the *dissemination* phase, user involvement helps in the integration of innovation in the existing processes of the user and facilitates training and internalization of knowledge. These activities are also beneficial for the user and support the implementation and confirmation stages of the adoption process.

To study the involvement of the user in the adoption process in the area of information systems development for disaster response and crisis management, case studies and exercises are most commonly used.

A case study is an often used method to achieve a realistic and comprehensive understanding of the user and the context in which he or she operates (Chan & Comes, 2014; Verschuren & Hartog, 2005). However conducting case studies in the disaster management field is challenging (Rodríguez, Kennedy, Quarantelli, Ressler, & Dynes, 2009). For example the high level of stress exerted on the intended users (professionals), the limited availability of (financial and other) resources or the chaotic environment, make conducting a valid and reliable evaluation difficult. In addition there are limited options for developers and researchers to physically conduct the research or connect to the users to obtain qualitative data and feedback (Van de Walle, Turoff, & Hiltz, 2009), because of geographical distance and inherent situational risks when travelling to a disaster area without proper training. Finally there are limited real opportunities for research, and when an 'opportunity' does present itself, it is typically unexpected and unpredictable. As such, the options to conduct rigorous case studies are limited and researchers often have no choice but to rely on secondary data.

Exercises and simulations, on the other hand, have the advantage of a controlled environment for the users to operate in and reducing the dependency on real world events. Exercises and simulations range from abstract analytical models to full, realistic field exercises (Alexander, 2000). However exercises also have their drawbacks. Full scale exercises can approximate reality but require significant resources to accomplish this. Furthermore, due to the large scope of a full simulation many additional factors can be introduced that inadvertently affect the outcome. Table top exercises and computer simulations require fewer resources. They can be fairly easily run over and over again, providing a reusable environment for user centered activities. However these simulations lack the required realistic context for valid results.

As case studies are often not feasible for the reasons outlined above, exercises and simulations are the de facto standard mode for user centered activities. For these exercises and simulations a balance has to be found between the required efforts and resources and the needed realism of the simulation. Serious games can provide such a balance as they can simulate certain relevant elements and eliminate others while leaving the experience for the players intact. It allows the designers to balance realism with efficiency, for example by replacing real people with dummies or damaged buildings by augmented/mixed reality interfaces.

Moreover, serious games can even put inexperienced players in a certain role, by providing specific briefings, in-game guidance and most importantly motivation (Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013). In this way serious games reduce the dependency on the availability of the (experienced) user. Therefore serious games seem to be able to provide an environment to support various user centered activities with both professional and non-professional players, in a lightweight scenario while maintaining the validity of the outcomes of those activities as illustrated in Figure 2 (Di Loreto, Mora, & Divitini, 2012).

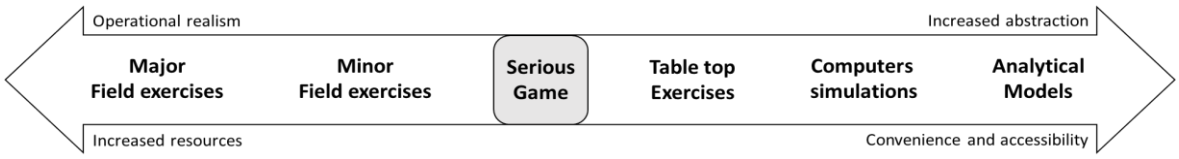

Figure 2 Types of exercises (adapted from Alexander, 2000)

In this paper, we examine several instances of the serious game 'Disaster in my Backyard' (DIMB) developed by the authors (Meesters & van de Walle, 2013) and further refined in different instances. We examine below how these instances, each with a specific audience, scope and focus, have supported user centered activities. The combined results allow us to assess the potential of serious games to facilitate the development process of innovations through user centered activities. Our main objective is therefore to illustrate the suitability of serious games to provide a resource-efficient environment, representing a realistic disaster context, in which innovative information tools and systems can be developed.

In the next Section, we first present the concept of serious gaming and provide the motivation for their use in the context of crisis response and disaster management. Building on the existing literature for serious games we identify several key components for the design of the game. From these key components we derive a workflow that has been used to adapt the DIMB game for use in the different instances. In Sections 3 we illustrate the application of the DIMB game in these instances and introduce the relevant literature, illustrate the application of the DIMB game and discuss how that instance facilitated user centered activities. Finally we conclude by summarizing our findings, and we outline possibilities for future work.

2 Serious gaming

Reduced to its formal essence, a game is according to Abt (1987) "an activity among two or more independent decision-makers seeking to achieve their objectives in some limiting context." Abt continues to add that "the problem with this definition is that not all games are a contest among adversaries –in some games the players cooperate to achieve a common goal against an obstructing force or natural situation that is itself not really a player because it does not have objectives". In a context of crisis response, the independent decision makers can be the officials of different organizations responding to a crisis, who need to cooperate to achieve a common goal (for example the rescue and relief of the affected population) while being obstructed by the natural disaster's many barriers to an efficient and effective response.

Serious games serve a different purpose then providing mere entertainment, but do not exclude it. In general however, a game for which the purpose differs from pure entertainment distinguishes the serious game from its entertainment variants. Serious games can be applied to a variety of environments, e.g. government, education, corporate, healthcare and crisis response (Michael & Chen, 2005), and can be used for a variety of purposes such as learning (Aldrich, 2003), explorative research (Geurts, Duke, & Vermeulen, 2007) or experimentation (Marsh, 2011).

2.1 Game design Workflow

When developing a serious game, two elements are important: the game *planning* and the game *delivery* (Gagné & Driscoll, 1975). Planning involves the definition of objectives (purpose) and the design of activities, while delivery is the presentation of these activities to the players. In earlier joint work, we have developed a design workflow that starts with the planning phase outlining the purpose, scope and context of the game. In the delivery phase the interaction, options and environment are considered. In addition to the planning and delivery phases we also introduced an *execution* phase with a specific step for evaluation. (Link, Meesters, Hellingrath, & Van de Walle, 2014). The various steps of the workflow, as shown in Figure 3, can be related to the roles of game designers who are responsible for *planning* and *delivery*; and the game managers who are responsible for the *execution*.

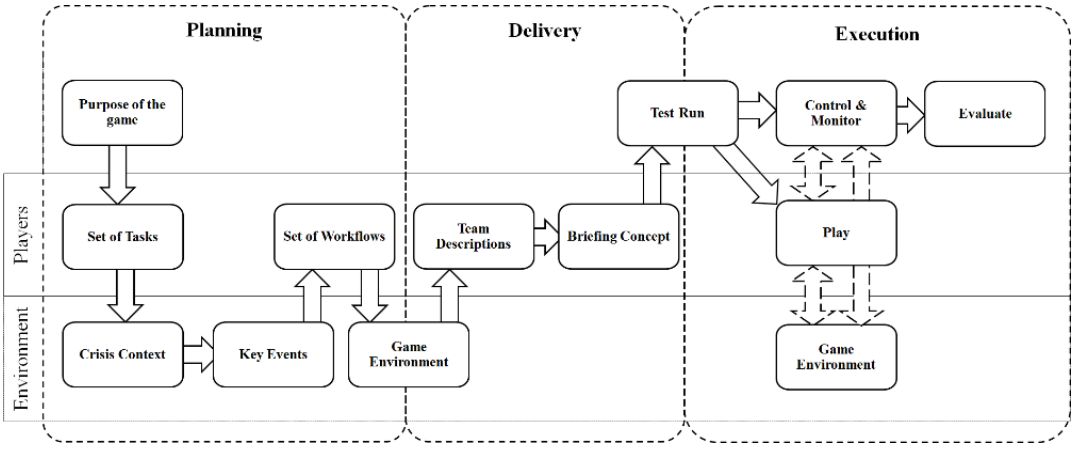

Figure 3 Game Design Workflow (Link et al., 2014)

As a first step, the game designers typically define the purpose of the game. When the purpose is set, the designers proceed to determine which tasks are appropriate for the players to handle, thereby also defining the scope of the game. To do so, the designers may draw on tasks from existing documentation and reference models. This enables the designers to quickly select building blocks for in-game workflow, for example using existing urban search and rescue manuals (Sjöberg, Wallenius, & Larsson, 2006). Next, designers select the appropriate crisis context or setting for the game environment and the key events or tasks (also called stages) of the game. These tasks are meaningfully combined into in-game workflows. These workflows are used by the designers for guidance while they further flesh out the game, creating a situation that can be "solved" by those who play the game. It is important not to confuse the workflows with the actual actions players take, as the game by itself does not dictate these actions but rather provides an environment with a large degree of freedom for the players to act.

With the knowledge of key events and in-game workflows, the design of the game environment can be completed, e.g. by defining key locations, important information to gather, but also the locations of affected people, materials etc. Knowing the exact game environment and the in-game workflows, the player or team descriptions can be fleshed out, including starting location, mission statement, and so on. In a next step, the targeted players are analyzed to develop an appropriate briefing concept. Concluding the game design, the game is played in a test run. This would preferably happen in the actual physical game location but could also happen virtually with a map, a game script, game descriptions and other materials.

The execution of the game then consists of the players playing the game while the game managers simultaneously monitor and control the game. By monitoring the moves of the players, which can be supported for example by real-time tracking systems, the managers are able to dynamically adjust the difficulty of the game. In addition, data that is relevant to support the user centered activities is collected during the game. After the game, the game managers and observers evaluate the game. Depending on the objective and purpose, the evaluation can be based on players' feedback sessions, rely on gaming data collected during the game or both.

2.2 The "Disaster in my Backyard" Serious game

Using the above design flow, we designed the serious game 'Disaster in my Backyard' (DIMB) to focus on challenges in information management, decision making and coordination during urban search and rescue operations (Meesters & Van de Walle, 2013). The game contains user centered activities such as creating shared situational awareness, establish efficient team communication, and develop resource planning.

Prior to the development of the game, four important requirements were identified. First, as indicated earlier, the focus for the game is on information management, decision making and coordination for urban search and rescue operations following a natural disaster. Second, we aim to provide a game that is playable without prior knowledge. Players do not need to have information management expert knowledge, nor need they necessarily be well-trained decision makers or coordination specialists. Third, the immersive experience is a crucial aspect of the exercise: the game may simulate certain elements but still must present the players with a realistic and representative experience. Fourth and finally, the proposed game is intended to be light-weight, thus the efficiency of setting up and running the game is important.

The crisis context of DIMB is set in an urban area where heavy rains have caused the rivers to burst from their banks and the flood waters necessitate the evacuation of the residents of the affected area, some of whom need urgent medical assistance. Throughout the game, events can be triggered to increase the game's level of difficulty, by introducing for example rioters who steal medical or other supplies or fires that erupt due to electrical shorts and prevent the responders' entrance to buildings and extraction of injured inhabitants. The workflows introduced in the game are all inspired by real-life processes, methodologies and operations used by humanitarian responders.

The DIMB game contains four specific game elements the players interact with: victims, markers, key figures, and resources. Victims are actors (or dummies) with a unique profile, detailing their background, their current situation and game information (i.e. time and location). *Markers* are information sources located throughout the game environment. *Key figures* are people with

specific skills who can provide expert assistance to teams, for instance construction workers or the police. Resources are items needed by the teams to conduct their search and rescue operations, such as medical supplies or vehicles.

To play the game, several teams are created, representing for example different organizations, and a team leader is appointed. During the briefing the players are informed that local authorities call upon the players to assist in the unfolding disaster. In addition players receive specific game instructions, including game rules and safety instructions. After the start of the game, the team leaders will be based in the control center, collecting and processing information, coordinating with others and communicating to their team. The rest of the team sets out to search and rescue the victims, based on the instructions provided by the team leader.

Several technologies are used to reduce the needed resources to run the game and to support the game managers during the execution of the game. Technology allows manipulating certain game elements to control the game, and monitor the overall game experience for the players. In addition various information sources can be inserted into the game through various channels, among which Twitter and other social media. Game levels are used to enable game managers to manage and trigger an information flow and update the game field accordingly.

The players are provided with a mobile DIMB application which simulates specific rescue tasks, such as providing medical care to a victim. Using the DIMB app, teams are able to scan QR codes that are located on victims or essential resources, in order to examine the status of a victim, the contents of a medical kit or undertake actions such as applying first aid (see Figure 4).

Figure 4 DIMB information marker and application (Meesters & van de Walle, 2013)

3 Instances of the DIMB Serious Game

To illustrate how serious games can be used to support user centered activities we introduce three instances of the 'Disaster in my Backyard' game. The first two instances of the game were played at the Information Systems for Crisis Response and Management Society (ISCRAM) summer schools on Campus Vesta, a professional training center for emergency services in Belgium, in 2012 and 2013. The third instance was played during a Logistics event in the city of Munster, Germany in early 2014.

3.1 DIMB at the 2012 ISCRAM Summer School

The DIMB game instance as played during the ISCRAM summer school was the very first game instance of the game. The game was played according to the setup described earlier using Twitter as a source for disaster information and mobile devices to track the progress of the responding teams. The use of a training area for local emergency and law enforcement services, including a fire training tower, a small village and a hospital as a gaming location, as well as the participation of volunteers, added considerable realism to the game. Dummies, wheelchairs, smoke machines and the presence of an active fire brigade all added to the realism of the game. The volunteers played roles as victims or supporting characters as rebels, police officers or construction workers. Finally, experienced first responders accompanied teams during the game and provided real-time feedback. Together with the standard game control mechanism discussed earlier, these 'mentors' enabled extensive control over the game and helped the players and game managers to reflect on the game outcomes.

This initial DIMB instance was intended to serve as an explorative introduction to the use of serious games for studying the reality of information management in disaster conditions. The game yielded positive reactions from the participants as well as the professionals involved. According to these professionals, the decision making process, uncertainty and communication difficulties are similar to real-life experiences. The participants were also able to play the game without prior specific knowledge of disaster management practices, yet the introduced technology allowed participants to experience circumstances as faced by emergency responders in reality. Lastly, the framework and technologies used in the game provided real-time control over the game and its components.

During the debriefing and evaluation of the game, the players indicated that the immersive experience has provided them with new insights, even as they have studied the field disaster response and crisis management before. The experience allowed both players and the supporting professionals to identify opportunities for improvement in disaster information management, and the controlled setting of the game enabled them to reflect on the actions and decisions taken.

3.2 DIMB at the 2013 ISCRAM Summer School

During the ISCRAM summer school the following year, another instance of the game was played. Prior to the summer school the organizers were in touch with the researchers from the Chair for Information systems and Supply Chain Management from the University of Munster who had developed GDACSMobile, a tool designed to support (crowd-sourced) data gathering. GDACSMobile enables disaster management professionals and affected population to share their observations from the disaster affected area by sending reports to the provider's server via the client application or via Twitter (Link, Hellingrath, & De Groeve, 2013). The 2013 summer school instance of DIMB provided the opportunity to use the game in combination with GDACSMobile. To this end the DIMB game was partially re-designed using the earlier introduced workflow to fit with the situation that the software solution was designed for.

The specific purpose of this game instance, in addition to the general purpose of DIMB, was to allow non-professional participants to experience the use of the tool for GDACSMobile in a realistic context. During the game each team would come across different pieces of information that, when put together using GDACSMobile, provided them with a common operational overview

that enabled all teams to improve the quality of their decisions. This resulted in an extension of the set of tasks based on functional requirements of GDACSMobile: the ability to find and collect information that is relevant for various disciplines. The crisis context and key events were not altered, as they already matched the scenario that GDACSMobile was developed for, i.e., search and rescue teams with different information needs operating in an unknown area with unknown damage. Specific consideration was also given to the team descriptions and the briefing concept, as the players were unfamiliar with GDACSMobile. The briefing included both the training in the tool as well as the workflows that are part of the game.

Also in this game instance the players and observers with professional experience indicated that, despite the introduction of workflows simulating operational procedures, the circumstances, challenges and context faced by the players result in the same behavior during a real-world deployment. Professional players and observers for example mentioned the experienced uncertainty, collaboration difficulties, and stress as realistic.

This specific game instance also yielded useful and valuable feedback for the developers of GDACSMobile. Players of the game noted specific points for improvements, based on their tasks and the overall purpose of the game. Players indicated for instance that improved process support would be needed in order to make the tool more useable in situations where users have limited time and training options. In addition users provided specific user-interface feedback and reported several technical and functional issues. This feedback was confirmed by the professional players, who provided similar feedback. Furthermore, the game design of this instance can be reapplied with minimal resources, allowing the designers and developers of GDACSMobile to re-evaluate their solution on a more regular basis. In addition to the reduced amount of required resources, the game enables the designers to invite non-professional players thus enlarging the pool of evaluators and testers.

3.3 DIMB at the 2014 Munster Day of Logistics

In April 2014 the ‘Tag der Logistik’, or Logistics Day, was held for the seventh time in Germany. The Logistics Day is a public event hosted by the German production industry, trade and logistics service providers, with a focus on logistics and supply chain management across Europe. As part of this day several activities were organized which focused on the theme of humanitarian logistics. One of the activities offered during this day was an instantiation of the DIMB game. The game was played in the Munster city center with the event visitors, including staff of the local government, representatives of the logistics industry and academic staff from the University of Munster. For this specific DIMB instance, the aim was to have the players reflect on their performance in a disaster situation. This reflection helps for example local government representatives to build knowledge on the difficulties that can be encountered when dealing with a disaster situation.

In this game instance no specific innovation was introduced nor was there a generic research objective. The purpose of this game instance was more tailored towards supporting the players to examine their own performance in a disaster setting. Because of the theme of the day the game was designed to focus more on logistical operations and management, as well as general coordination allowing participants to use their own knowledge and experience in the game. The set of tasks of the game was therefore expanded to include more logistics tasks, such as finding and delivering supplies, keeping stock and making decisions when and where to deliver them, in

addition to existing information management processes. These tasks were based on the humanitarian logistic reference processes (Blecken, 2010). The crisis context was also altered to refer to an airplane crash resulting in casualties across the city center of Munster.

The game environment was divided into three separate areas. In each area the team was divided into three 'field' sub-teams each with their own workflow: an assessment team, a logistics team and a rescue team (see Figure 5). The assessment team was tasked with finding and 'processing' the markers, containing information on materials or casualties. The information gathered by the assessment team then had to be communicated to the logistics team (materials) and rescue teams (victims). The job of the logistics team was to make sure that the rescue team received the materials they needed. The rescue team was responsible for 'treating' the victims, using the provided materials. In addition to the three field teams, a (small) coordination team was formed that would facilitate communication and coordinate with the teams operating in other subareas of the affected area.

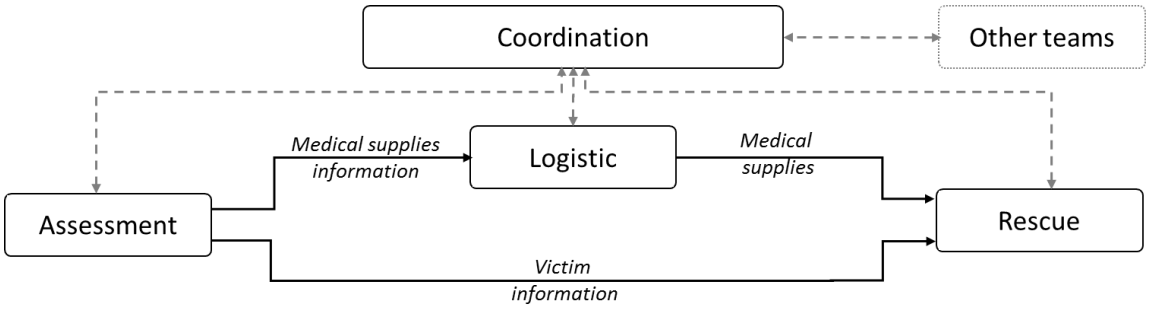

Figure 5 Linked tasks during DIMB instance Day of Logistics

The team descriptions played an important role in this game instance. The game instance included specific workflows that required specific knowledge and competences such as understanding logistical dependencies, maintaining an overview and coordination between different teams. In other words, the game instance was setup to match the level of the players, providing challenges related to their field of work (i.e., logistics), but in a different (disaster) context.

After completion of the game the participants were asked during the debriefing to evaluate their own performance during the game. Specifically the players were asked which challenges they faced, what insights they had gained, and the lessons they had learned. A large majority of the participants indicated that they had problems in creating and maintaining a situational overview. Furthermore the respondents indicated the coordination between the teams as a problem. With different teams to coordinate, most players indicated that this coordination was challenging. Players also experienced communication difficulties, mainly resulting from sharing a single radio channel, without establishing a proper communication protocol. While the game provided challenges to the participants that required them to adapt and re-apply their prior knowledge, overall the participants agreed that the game experience helped them towards being more prepared to deal with logistics in a crisis context.

4 Findings

In this section, we reflect on the three instances of the DIMB serious game discussed in the previous section to assess whether serious games contribute to increased user involvement in the innovation development process. Our assessment comprises two aspects. First we describe to what extent the DIMB serious game instances meet the following four game requirements: (1) was a realistic environment centered on decision making and information management provided; (2) were the players offered an immersive experience of a post-disaster setting; (3) could the participants play the game without the need for in-depth know-how of rescue operations; and (4) did the game balance realism with efficient resource-use. Secondly, we examine whether and how the different DIMB serious game instances facilitate user centered activities for research, development and testing, and dissemination.

4.1 Meeting the requirements

From the debriefing sessions conducted with the players and the professional observers in each instance, we have learned that the players experienced similar challenges as those experienced by professionals in a real disaster setting. These challenges are for example related to information management and coordination while confronted with a highly dynamic and volatile environment, as per the purpose of the game instance. Examples of generic difficulties of the disaster environment faced in the game include time pressure and uncertainty. More importantly, because the game takes place in a real environment supported by augmented reality, several elements were present in the game that could not be integrated in table top simulations, such as physical distances between locations on the training grounds, orientation issues resulting from only limited knowledge of the terrain, and a clear lack of shared (situational) views.

The players themselves indicated during the debriefings that, despite knowing that they participated in a game, they felt compelled to 'perform well'. The fact that the 'victims' were dummies and resources were simple sheets of paper stamped with QR codes did not influence their motivation. For example, during the game instance in Munster, some participants stopped (real!) traffic so to cross a road quickly because they 'were on a rescue mission'. In other instances participants were reluctant to stop because victims 'were still out there'. This behavior shows that the game is able to introduce a high level of motivation, engagement and immersion for the players.

Finally the efficiency for setting up and playing a game instance must also be considered. Because the game relies on augmented reality to be played a mapping of the scenario to the (area of the) location has to be made for each game instance. This requires the game managers for example to define positions for the markers as well as update location-specific names. Currently this is a labor intensive task, but this could be fairly easily automated in the future. The first two instances introduced in this study were played at Campus Vesta, a training facility for professional responders, and provided excellent facilities and materials to run the game. The third instance was played in the city center of Munster and as such did not provide dedicated facilities. However with some adoptions (e.g. replacing dummies with paper markers) the game could be played at this location as well while maintaining the required game experience. In addition, the mobile application, the markers and (simulated) resources make the game re-deployable and ensure efficient resource use as they replace a large portion of the materials (e.g. medical kits, actors, and equipment) otherwise required for simulations or exercises.

4.2 Facilitating user centered activities of research, development and testing, and dissemination

The key objective of this research is to illustrate the potential of serious games to support user centered activities in the development of information management and decision support innovations in the field of crisis response and disaster management. We examine how the introduced game instances contributed to support user centered research, development and testing, and dissemination activities.

4.2.1 Research

Often serious games have a strong focus on the learning objective for the players (Aldrich, 2003). However objectives for serious games can also include the exploration of new ideas, for example policy and strategy changes (Geurts et al., 2007), in which not (only) the players are part of the objective but also the outcome of the game has a specific value. Serious games can also be deployed as an environment for experimentation in which gaining an understanding of the players is the motive (Marsh, 2011). As such, serious games could even be tailored further to provide an environment for more formal explorative research.

In all of the introduced instances the serious game provided valuable insights and results. Depending on the scenario, game setup and implementation, these results have a specific value for researchers, developers or professionals. For example a game with a strong focus on testing and evaluation of a specific tool will yield more results related to usability than a game centered on testing decision making processes. The first DIMB game instance in particular has enabled the participants to gain a better understanding of the challenges faced by disaster response professionals. This understanding helps researchers and developers to identify opportunities for innovation by combining their own domain knowledge with the insights gained from the game.

4.2.2 Development and Testing

Newman and Noble (1990) and Atkinson (1999) amongst others have shown that user involvement is strongly recommended as a technique of successful systems development. Sommerville and Kotonya (1998) propose to improve user involvement through evaluation during development so to provide (continuous) feedback**.** This helps developers to not only analyze the users but also verify the validity of their assumptions about the use of the innovation in realistic tests. This approach optimizes the design of information tools towards the user's behavior rather than dictating the behavior needed to use the developed tool (Landgren, 2007).

Specifically in the instance where the DIMB serious game has been used to evaluate an innovative information collection and sharing tool, interesting insights were gained. More importantly, the lightweight, realistic environment provides developers with the option to conduct more frequent evaluation and testing sessions while maintaining the validity.

An interesting observation made by working with professionals during the game instance designed around GDACSMobile is that the evaluation does not only hold importance for the developers of systems to assess the quality and adoptability of their developed systems. Evaluations also enable professionals organizations to make a well-considered selection in software to be used (Jadhav & Sonar, 2009). A serious game environment, modelled according to a specific objective (issue or challenge) for the end user, would allow them to test, assess and evaluate various alternatives.

4.2.3 Dissemination

As argued earlier, in addition to the conception and development, the dissemination (deployment) of innovations is another important element in ensuring a high level of adoption. For example, through dissemination, users gain knowledge and skills needed to (optimally) use the introduced innovations (Norris, Stevens, Pfefferbaum, Wyche, & Pfefferbaum, 2008). This includes the integration (embedment) of innovations in existing procedures. (Ketelhut & Schifter, 2011). The improved use of innovations depends on building knowledge, training skills and integration.

However a study by the National Learning Center shows that classroom exercises have little retention potential: only about 5 percent of what people hear in a classroom setting is retained (DeKanter, 2004; Wood, 2013). To achieve a higher retention rate, participatory methods must be used. For example with a practical exercise around 75% of the information is retained. When students reflect upon themselves and others, the retention rate can even go up to 90% (Dearing, 1997; Fry, Ketteridge, & Marshall, 2008). Practical application helps in internalizing skills and knowledge. Practical use also improves the ability of students to recall the knowledge when needed, particularly when the knowledge and skills are not accessed on a regular basis or in a stressful setting (Keith & Frese, 2008). Therefore (practical) exercises as a teaching methodology are already widely applied by professional crisis responders (Romano & Brna, 2001).

As mainly illustrated in the third DIMB instance, serious games can provide an environment for professionals to learn to apply their prior knowledge, even when that knowledge has never been applied by the players in the new and radically different context of a disaster. In the other DIMB instances the professionals also noted the value of a serious game as a training environment focused specifically on information management and decision making. The game enables the collection of specific data that can be used to guide the evaluation, such as the time required to rescue a victim or an up to date overview of the victims rescued. Using the data as a means for reflection, this use could even extend beyond the training of professionals to familiarize non-professional players with the context of a disaster environment.

5 Conclusion

New opportunities for disaster and crisis response continue to emerge in the form of innovations in information management and decision support. These innovations provide the potential to humanitarian and crisis response entities to improve their operations. However, the mere potential of these innovations is not a sufficient condition to actually generate these improvements. Rather, it is the (level of) adoption of these innovations that largely determines whether an innovation's potential will be realized. In order to improve user adoption, a close collaboration with the user is necessary. This collaboration plays an important role in every stage of the development process. In the conception stage, user centered research helps in understanding the problems faced by the users, the opportunities that are present, and in a broader sense the understanding of the user-context. During the further development of the innovation, user-involvement ensures a proper alignment with the requirements and expectation and supports rigorous user testing.

However, user centered activities in the field of disaster management and crisis response are difficult, especially when a realistic context is required for assessing the validity of the findings. As illustrated in the three DIMB instances, serious games have the potential to focus on a specific

area of the disaster response, enabling the effective simulation of the non-relevant elements of an exercise while keeping the key processes and challenges intact. Through the DIMB game instances we find that serious games can indeed facilitate user centered activities supporting user adoption in the innovation development process.

5.1 Limitations & future research

At a practical level the DIMB serious game needs further improvement and continued research regarding the effective use of the game ingredients to provide further realism. The design of adequate scenarios is important in considering the further development of DIMB as serious game for various purposes. Different scenarios could be developed and easily deployed within the game framework we introduced earlier. Crisis information sources and social media can be used as input to develop scenarios dynamically, depending on the response decisions made from these. By adding more information sources and tools to the game, more realistic (information management) scenarios can be employed. Better capturing technology could be used to gather research data from the game, for example by using mobile devices to track locations, keep track of time and information use. In future instances of the DIMB game, we will not only capture these data but also present them directly as feedback to participants.

Finally, one of the most important aspects of the serious game is its 'calibration', or the ability of the game to represent the relevant key elements while (effectively) simulating other elements. Follow-up research is needed to determine how such key elements can be identified and accurately represented when designing a serious game

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