

# Serious Games as Experiments for Emergency Management Research: A Review

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## ABSTRACT

Serious games and virtual environments are increasingly used for emergency management training and research. The development of these technologies seems to contribute to a solution to some problems in the existing literature on emergency management which is mainly based on case study research. However, using virtual technology for research also introduces new difficulties. This paper describes the advantages and drawbacks of using serious games for research and reviews eight recently published studies that make use of virtual environments. The review focuses on the external validity of serious games as this is a challenging issues for research that involves virtual environments. The paper concludes with some recommendations to increase the external validity of future research with serious games.

## Keywords

Emergency management organizations, experimental research, external validity, serious games.

## INTRODUCTION

To improve our ability to deal with emergencies, we have to understand how emergency management organizations respond to such events. Emergency management research frequently addresses organizational issues in emergency management. However, the body of literature that has been developed around these issues is primarily based on case study research (Canton, 2007). Case study research has some important shortcomings in the context of emergency management. Case studies generally focus on high-profile and unique events that are difficult to compare. This hampers the development of general lessons for emergency management. Also, case study research is often based on interviews and reports instead of direct observations, which can result in a shortage of useful information. These disadvantages combined make that emergency management literature is generally fragmented and often inconclusive.

An alternative to case study research is to study emergency management during simulations and exercises (Lee, Trim, Upton and Upton, 2009). Emergency management organizations arrange small and large scale exercises to prepare for real events. Besides preparation, such simulations can be used for research (Borodzicz and van Haperen, 2002; Bergström, Dahlström, Henriqson and Dekker, 2010). Major advantages of studying simulated events are direct access and possibilities for manipulation and control. Direct access to the emergency scene enhances possibilities for data gathering. And through manipulation and control it is possible to generate comparable emergency situations to study the behavior and performance of emergency management organizations systematically. This makes simulation based research a powerful method for making inferences. Emergency simulations have undergone some major changes in recent years through the increasing use of virtual training environments and serious gaming technology. Such technologies offer great opportunities for training and research but using serious games for research also introduces new difficulties, mainly with regard to the external validity of research outcomes.

The aim of this article is to address present concerns regarding the validity of serious games for research in emergency management and to recommend several possibilities to increase the validity of future research. To achieve this aim, the use of serious games for emergency management research will shortly be described

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together with its main benefits and drawbacks for research. Second, a review of eight studies that use serious games for research is presented and discussed. Based on the review, several recommendations for future research are presented.

## **SERIOUS GAMES FOR EMERGENCY MANAGEMENT: TRAINING AND RESEARCH**

The number of publications dedicated to examples of serious games for emergency management is growing rapidly. Virtual training environments have been developed for traditional emergency services (Jenvald and Morin, 2004; Metello, Casanova and Carvalho, 2008), for triage training (Dumay, 1995; Jarvis and de Freitas, 2009) and many industry specific applications (e.g. Mallett and Unger, 2007). Serious games for emergency management are primarily developed in the form of virtual environments in which all kinds of incidents can be simulated (Taber, 2008). Emergency services and industrial firms use these environments to train their operational and tactical staff for decision-making and emergency response skills (Crichton and Flin, 2001). The popularity of serious gaming technology for emergency management lies in its low costs in comparison to real-life simulations and the fact that emergencies can safely be simulated (Smith, 2004; Taber, 2008). Besides training, serious games are also believed to hold potential benefits for research (Van Eck, 2006). The rise of virtual and gaming technology seems to increase the possibilities for manipulation and control which implies increasing possibilities for experimental research on emergency management. However, the use of virtual technologies also presents several difficulties.

### **The benefits of using serious games for emergency management research**

Three basic advantages of using serious games for research will be mentioned. The first advantage is extensive control in complex situations. It is difficult to control variables like the weather, the position of heavy objects or the consecutive occurrence of multiple events in real life simulations. Control over complex settings is important to generate comparable situations for research. Serious gaming environments can be simultaneously complex and controllable and computerized standardization makes serious gaming experiments also repeatable. Control and repetition offer great opportunities for research. Second, serious gaming environments have the ability to simulate situations that are impossible to mimic in real-life or in a laboratory. And third, serious games provide large surface validity. Although virtual reality is not real, fire shown in virtual environments can have more resemblance with real fire or smoke than the means used to imitate fire and smoke during many real-life exercises (Jenvald et al., 2004).

### **The challenges of using serious games for emergency management research**

Some challenging issues should be discussed as well regarding the use of serious games for research. First, the analysis of the effects of treatments on outcomes in serious games can be difficult because of the complexity of scenarios. Serious games can involve naturalistic and complex environments containing many variables. This can create the same analytical difficulties that are encountered in case study research (Morton and Williams, 2008). For example, laboratory research on decision making eliminates as many variables with the potential to influence the outcome as possible. Moving from a laboratory to a virtual environment increases the realism of the task environment but also introduces variables that must be accounted for during the analysis of outcomes. A second challenge lies in several threats to the validity of outcomes of serious gaming experiments. Shadish, Cook and Campbell divide experimental validity into four types: internal, construct, external and statistical conclusion validity (2002). Although research with serious games can be problematic with respect to all four types of validity, it is external validity that requires specific attention. External validity refers to the extent to which inferences based upon an experiment hold over other subjects, settings, treatments and outcomes (Morton et al., 2008). The main difficulty with the external validity of research with serious games relates to the translation of outcomes towards other settings. Serious gaming experiments involve a simulated and virtual environment. The behavior of subjects and the effects of treatments on outcomes can be influenced by the fact that the environment is virtual instead of natural. The potential difference between behavior within a virtual environment and a real environment poses a threat to the external validity of outcomes of research with serious games. However, external validity is not only based upon the transferability of research outcomes to other *settings* but also on the transferability to other subjects, treatments and outcomes. To gain more insight in how threats to external validity play a role in research with serious games, the next paragraphs present a review of recent studies that use serious games for emergency management research.

## REVIEW

The studies presented in the review have been selected from publications in the ISCRAM proceedings and the Journal of Contingencies and Crisis Management from 2006 onwards. Criteria for selection were a (quasi) experimental research design, the use of serious gaming technology and a focus on organizational aspects of emergency management like group decision making or team performance. During the review, the selected studies have been assessed on four aspects; participants, treatment, outcome and setting. These aspects correspond with the four dimensions that determine the external validity of a study. The assessment focused on problems that might occur during the translation of findings of the studies to other subjects, treatments, outcomes or settings, whether these problems have been addressed and whether solutions to these problems have been presented or implemented. A general overview of the review is presented in table 1.

Study	Participants	Treatment	Outcome	Setting
(Te Brake, Van der Kleij and Cornelissen, 2008)	15 teams, 45 participants (students)	Connectivity (strong or weak), map orientation (north-up or heading-up)	Team performance (victims rescued, participant ratings)	Virtual environment based on Unreal Tournament
(Berggren and Johansson, 2010)	24 teams, 73 participants (students)	Visibility of the environment (limited, partial or full visibility)	Shared understanding, situation awareness, team performance (questionnaire, subjective assessment, system recordings)	C3Fire microworld
	3 teams, 9 participants (military professionals)	Command method (similar or different communication methods)	Shared understanding (factor ranking, subjective assessment)	Swedish Armed Forces Crew Training Facility (BTA)
(Granlund, Granlund, Dahlbäck and Johansson, 2010)	18 groups, 108 participants (municipal professionals)	Global information system (GIS) module (virtual GIS or paper maps)	Communication (question type, information type, order type, or other)	C3Fire microworld
(McLennan, Holgate, Omodei and Wearing, 2006)	28 teams, 140 participants (students)	Communication structure (open or restricted)	Incident management team (IMT) effectiveness (landscape saved, subjective assessment)	Networked Fire Chief (NFC)
	40 teams, 120 participants (students)	Command style (intentions or detailed orders)	Incident management team (IMT) effectiveness (landscape saved, subjective assessment)	Networked Fire Chief (NFC)
	54 teams, 162 participants (unknown)	Levels of available resources (information, appliances, tactical control, means for communication)	Incident management team (IMT) effectiveness (landscape saved, subjective assessment)	Networked Fire Chief (NFC)
(Bergström et al., 2010)	16 teams, 80 participants (students and professionals)	Domain expertise and experience (education, years of experience)	Team coordination (qualitative assessment of interpredictability, common ground and directability)	Mid-fidelity ship bridge-simulator

**Table 1. Overview of the review**

### Participants

A threat to the external validity of serious gaming experiments arises when participants in a study differ significantly from subjects to which the outcomes of a study are transferred. Table 1 shows that more than half of the reviewed studies use students as participants for serious games. Using students can pose a threat to the external validity of research outcomes as the behavior and performance of students might differ significantly from the behavior of trained or experienced emergency management professionals. Not all studies that involve students address this problem explicitly. However, studies that do address this problem provide convincing

arguments why the outcomes can be transferred to professional emergency managers. Arguments are that the involved students received sufficient training to level professionals or that the task involved did not require specific knowledge or skills.

### *Treatments*

Problems with the validity of treatments can occur when a single treatment is used to represent a broader range of treatments or a general concept (Highhouse, 2009). The review pointed out that most studies use a single treatment with two distinct values. This does not pose a problem for some studies as they explicitly aim to test a single treatment. For research on more general concepts, like communication or command styles, using a single treatment can pose a threat to external validity as the outcomes might not hold over other treatments. It was found that none of the studies selected for the review addresses this problem explicitly.

### *Outcomes*

A threat to the external validity of serious gaming experiments occurs when a narrow indicator of the research outcomes is used. Using a narrow indicator can result in difficulties when transferring the outcomes of a study to a broader causal relationship of interest. Outcomes are assessed extensively in most studies selected for the review. Besides explicit performance indicators, most studies use additional indicators or subjective assessments to judge different aspects of the outcome. Moreover, most studies explicitly address the vulnerability of using a narrow indicator for the outcome variable.

### *Settings*

As explained above, the setting of serious gaming experiments poses a major challenge to the external validity of research outcomes. Serious games can differ significantly from real emergency scenes which make it doubtful whether outcomes of research performed with virtual environments hold over real settings. The review brought forward that several studies do not address this issue. Although similarities between the virtual environment and reality are generally described, potentially important differences do not receive further attention. Pointing out these differences is crucial to determine the external validity of the outcomes of serious gaming experiments. It should be mentioned that some studies indicate the differences between the environment used and reality extensively.

## **CONCLUSION AND RECOMMENDATIONS**

Serious games are increasingly used for training and research in emergency management. The advantages and potential benefits of using serious games for research have been described together with potential difficulties. It is external validity that forms the primary concern when doing emergency management research with serious games. A review of eight recently published studies pointed out that there are currently three areas of concern. Involving professionals in research with serious games is difficult. This does not present a remarkable finding in itself as involving professionals in research is generally more difficult than involving students. However, as serious games are relatively easy to develop, it might be the involvement of representative subjects that becomes a limiting factor. To cope with this problem, two strategies are suggested. First, the differences between participants in a study and the target group should explicitly be mentioned. The review showed that it is sometimes possible to convincingly argue that research findings can be transferred between different groups. Second, research can be combined with training. Although training objectives might restrict possibilities for research, it seems worthwhile to search for fruitful combinations. When research with serious games aims to contribute to our understanding of more general causal relationships in emergency management organizations, it is necessary to address the relation between general concepts and the treatments provided in the research. The review brought up that this relationship is only infrequently addressed. When research is not aimed at testing a specific treatment, it is recommended to address the relation between specific treatments and general concepts explicitly to support the development of an integrated body of experimental research. A remarkable finding of the review is that several studies do not address the differences between the virtual environment used for the research and the real life emergency situation that is represented. It is recommended that these differences are stated explicitly as the value of serious games for research in emergency management depends strongly on a clear indication of the validity of the outcomes.

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