Everscape: The Making of a Disaster Evacuation Experience

Eurico Doirado
National Institute of Informatics
2-1-2 Hitotsubashi, Chiyoda-ku,
101-8430, Tokyo, Japan
eurico_doirado@nii.ac.jp

Mignon van den Berg
Department of Transport & Planning, Delft University of Technology, Stevinweg 1, 2628 CN, The Netherlands
M.vandenBerg@tudelft.nl

Hans van Lint
Department of Transport & Planning, Delft University of Technology, Stevinweg 1, 2628 CN, The Netherlands
J.W.C.vanLint@tudelft.nl

Serge Hoogendoorn
Department of Transport & Planning, Delft University of Technology, Stevinweg 1, 2628 CN, The Netherlands
S.P.Hoogendoorn@tudelft.nl

Helmut Prendinger
National Institute of Informatics
2-1-2 Hitotsubashi, Chiyoda-ku,
101-8430, Tokyo, Japan
helmut@nii.ac.jp

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Abstract
Disaster evacuation studies are important but difficult or impossible to conduct in the real world. Evacuation simulation in a virtual world can be an important tool to obtain data on the escape and choice behavior of people. However, to obtain accurate "realistic" data, the engagement of participants is a key challenge. Therefore, we describe the making of an engaging evacuation scenario called "Everscape", and highlight the collaborative effort of researchers from the informatics and transportation fields. Further, we describe encouraging results from a pilot study, which investigates the level of engagement of participants of the Everscape experience.

Author Keywords
Participatory simulation; user experience; collaboration

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces - Evaluation/methodology, Prototyping, User-centered design, Evaluation/methodology; D.2.6 [Software Engineering]: Programming Environments - Interactive environments.

General Terms
Design, Human Factors, Experimentation

Introduction

Participatory simulations have already empowered researchers in several fields such as agriculture [4] or urban traffic [2] to study phenomena that are impractical or impossible to analyze in the real world. For instance, evacuation researchers want to study human response behavior in the case of a tsunami or flood. In a virtual world, behavioral data can be collected at a higher level of accuracy and reliability than questionnaires based on "what-if" scenarios, which is the currently prominent data collection method of evacuation researchers. A main factor is the immersion of the user in the virtual scenario and the emotional engagement in decision-making.

Evacuation researchers have a great need for simulations that allow them close the gap between mathematical models on decision behavior in case of disaster and sparse data on realistic behavior in evacuation situations [3]. Therefore, in this paper, we describe the making of Everscape, a realistic simulation and user experience of an evacuation scenario. We also briefly summarize a pilot study we conducted on participants' engagement in the simulation.

Design

Research requirements

The transport and evacuation researchers from Delft University of Technology wanted to study the behavior of people that are forced to escape in extreme urgency, such as a tsunami, whereby all subjects are expected to start at the same location and can choose among three escape routes, using different travel modalities with different levels of risk and travel time.

Concept

In response to the requirements, we choose a helicopter escaping from the island as it is easily conceivable as the sole escape point in the case of a tsunami (see Fig. 1). A short car route is located seaside and a longer car route passes through the mountains. To emphasize the risk of the short route, there is a bridge that may collapse due to the earthquake and its frequent aftershocks. We also offer to use a train that connects the heliport and the beach as the third route.

Figure 1. The island on which the scenario takes place

With these elements we covered the research requirements from the traffic engineers. However, to make the scenario work for an evacuation study, the perspective of the participant, the fiction, was missing. Hence we put the participant into the role of VIP who arrives on the island by helicopter to assist a concert on the beach. Then suddenly an earthquake happens, a tsunami is coming and the participant needs to return to the heliport as quickly as possible.

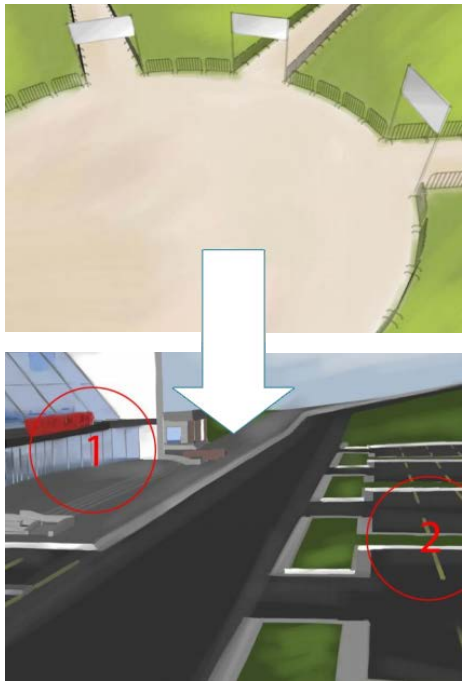

Figure 2. Early design flaws were identified with the storyboard. Here the participants had to make the choice to either escape from by train or by car – only later would they choose between the short and the longer route. Initially, however, we thought that each option would be clearly presented to the user at the same time

Storyboard

Storyboarding is a useful technique for a designer to start sketching the user-experience he or she wants to create [6]. It serves as a rapid-prototyping tool which let us solve problems often created from unconscious choices we make when designing. Using this method, we could shape the whole experience and fiction from a user point-of-view. Importantly, the transport and evacuation researchers could provide useful input about critical situation such as the moment in which participants had to effectively choose their transportation mean and route (see Fig. 2).

The storyboard also helped us to set a common vision very clearly among team members in the project's development. In our multi-disciplinary team, everyone has a different background, different levels of technical expertise and more importantly, everyone is concerned about a different aspect of the joint project. By establishing the storyboard as common vision, technical problems can be discussed effectively among team members. For instance, the transportation researchers wanted the bridge to collapse after a certain number of participants used it to render the short route ineffective. The purpose was to study the adaptation process of the other participants. Using the storyboard, we could easily explain why this approach could not be enacted with certainty in an online environment as, for instance, multiple users might cross the bridge at the very same time.

Emergency feeling

A key aspect of the evacuation simulation was to instill a sense of emergency to the participants. They had to feel fear about the tsunami and the necessity to make escape decisions quickly.

Several elements were involved in the creation of this experience: (1) participants would experience the earthquake; (2) they would then be presented a tsunami alert which shows concisely what happened and the available escape routes; (3) the sound ambience would reflect an evacuation setup (alarms ringing, people panicking and screaming); (4) the weather would gradually turn frightening, it would start to rain, the wind would grow stronger, until finally the thunderstorm starts; (5) earthquake after-shocks would be felt through the rest of the simulation.

Prototyping

The developer team agreed on a development process based on the SCRUM approach. We would plan a list of features to implement within three weeks, test them with the users and gather feedback from the transportation researchers from Delft. Each iteration would improve over the previous one and introduce new features. We here-after briefly present each of the four iterations we made.

First iteration

In the first iteration we used the DiVE (Distributed Virtual Environment) developed at the National Institute of Informatics to quickly create an online world in Unity3D. Inspired by the industry's state of the art, we implemented a first version of the avatar control scheme. Along the way, the island and its main elements started to take shape.

The feedback of this iteration allowed us to learn more about the end-user of the simulation. Not all users were gamers and the control scheme involved a mix of mouse and keyboard – something that was rather unintuitive for most. Most importantly, they would not

have time to train on the simulation. The transportation researcher would conduct an experiment in which they would ask the participant to play the simulation once, and once only, as the surprise factor is crucial to the decision behavior in the emergency situation. It had to work on the first try and thus we simplified all the controls. Participants would only use the four arrow-keys of the keyboard through the whole simulation.

Second iteration
In the second iteration the transport modalities were implemented. Participants would start at the concert and then escape using a car or the train. The earthquake would trigger three tsunami waves and the weather would slowly transform to bad climatic conditions.

We noticed that participants found it difficult to control the cars. Steering was too sensitive and they felt that the viewpoint was too detached, lessening the sensation of immersion. Their feedback had a serious impact as it fostered some discussion regarding the data researchers were interested in. The trajectory and intentions of the participants weighed far more than their capabilities to drive a car in a simulation. Thus we favored an approach that would be easier to control and instead of a purely accurate physics simulation, we added a steering assistant that would help participants realign the car with the road tangent.

Third iteration
Besides the previous changes we also implemented the special effects that would simulate an earthquake in the virtual world as well as the other critical elements of the simulation (e.g. the bridge collapsing, the helicopter flying away).

Figure 3. Participants learn how to handle the car on the way from heliport to the concert

The feedback on this iteration marked a turning point. Despite our best efforts, participants were still having difficulties to control the car. Although they would only voice their complaints regarding the car controls, we personally felt that too many elements were being introduced to the evacuation simulation at the same time, that is, we were asking participants to escape in a hurry, make travel choices and learn how to drive.

After considering several alternatives, we decided to take a step back and redesign the experience flow. In our fiction, the participants would come to the island to assist to a concert. We would use this argument to make them experience the full story, including the driving, and introduce elements at a much slower pace. Instead of starting directly at the concert, they would arrive by helicopter and have to pick a car. They would thus drive themselves to the concert and while discovering the island topology by themselves they would be able to take their time to adapt to the controls of the car (see Fig. 3).

Final version
For the final version we focused on finishing elements that were important but rather non-interactive. We included the breaking news item that would disclose the evacuation information to the participants, as well as the introduction and ending cinematic. The emphasis was on delivering a complete experience to the user.

Pilot Study

To better understand whether the design choices we made were having the expected outcome, we performed a pilot study (see Fig. 4). The experiment also served to obtain driving and travel behavior data, which is of key importance for our collaborators from the transportation field. For that purpose, a collaborator from Delft (the second author of this paper) visited the National Institute of Informatics in Tokyo.

Figure 4. Participants are gathering at the concert before the earthquake

Experiment
Twenty-one people participated in the pilot study. They were all students or researchers from the National Institute of Informatics, aged between 25 and 35. Only one participant was female. They all played at the same time and no one ever tried the simulation before. Subjects were rewarded 1,500 Yen (about 20 USD).

We designed the user experience with the assumption that deeper emotional involvement in the simulation would help to gather useful data. We used the EGameFlow questionnaire [1], a validated questionnaire based on the GameFlow [5]. The GameFlow is typically used in cases in which we want to assess the level of engagement of participants in games. This questionnaire contains 42 validated Likert items divided into 8 Likert scales.

Results of EGameFlow Questionnaire
Table 1 shows results of each category whereby 1 represents the lowest score, 4 neutral and 7 the maximum. We observe that participants could maintain a rather high level of concentration (5.47) through the simulation. They felt that simulation goals were clear (5.80) and that the feedback they received for their progress was good (5.46). The near neutral score in challenge (4.33) might be due to the fact that the simulation is rather short and does not adapt to each individual – the challenges are identical for everyone independently of their own skills. Participants felt that they had control over their own play through (autonomy = 5.10) and were in a state in which they forgot about their surroundings (immersion = 5.06). The social interaction was rated rather poorly (3.66) as space negotiation while running to the cars or driving was their main form of interaction. Finally, participants felt that after playing through this simulation their overall knowledge of extreme events (e.g. impact, safety procedures) increased, which is a desirable side-effect of this work.

Category	Mean	Std. dev.
Concentration	5.47	0.78
Goal clarity	5.80	0.60
Feedback	5.46	0.83
Challenge	4.33	0.86
Autonomy	5.10	1.05
Immersion	5.06	1.17
Social Interaction	3.66	1.23
Knowledge Improvement	5.26	1.16

Table 1. Results from the EGameflow questionnaire [1]

These results are encouraging and suggest that overall, the pace of the simulation is adequate, and that it is clear and engaging for the participants. They would however benefit from more possibilities to interact with one another (either to collaborate or compete) and from an adaptive challenge – a problem in multi-user simulations. Further, we believe that the inclusion of a chat message may help to foster the feeling of social interaction between the participants.

Collected Driving and Travel Behavior Data

The data we provided to the transport and evacuation researchers is two-fold: (1) driving and travel behavior data, logged from the in-world session of each participant (e.g. positions, route choice); (2) questionnaire data. While these results are not the focus of this paper, it is important to note that this was the first time that our collaborators from Delft could collect revealed preferences of people (the chosen escape route) other than asking them after some event, which is obviously impractical or impossible in the case of a major disaster, and could compare then to their stated preference (the questionnaire).

Conclusion

In this paper we describe the design process of Everscape, a participatory simulation in which participants have to escape from a tsunami. We analyze the several steps we took to instill the most effective user experience, a mandatory aspect when collecting useful data for the transport and evacuation researchers. We conducted a pilot study, in which we analyzed participants' feedback regarding their own engagement, and related dimensions. The study shows that we largely met our design goals, but still have to improve the social aspect of the simulation.

Together with transport and evacuation researchers, we aim to establish such kind of participatory simulation as a tool to gather large-scale behavioral driving and travel data and personal feedback on extreme events such as tsunamis or floods with an unprecedented level of accuracy.

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