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Abstract

We assessed the effects of the addition of dynamic visual elements and sounds to a levee patroller training game on the appraisal of the environment and weather conditions, the engagement of the users and their performance. Results show that the combination of visual dynamics and sounds best conveys the impression of severe weather conditions and most strongly influences the appraisal of the environment. Moderate effects on the engagement of the participants were found.

Keywords--- 3D models, virtual environments, affective appraisal, visual dynamics, soundscapes, serious gaming

1. Introduction

3D models of the built and rural environment are widely used in desktop applications for architecture, landscape visualization, and (serious) gaming. The appraisal of a real environment and of a 3D model may differ considerably, as a result of choices made in the modeling process, characteristics and restrictions of hardware, software and display, and the perception of the user [1]. In a series of experiments we explore these differences, and aim to identify the main factors affecting them. One of our goals is to determine the validity of 3D models when used for training and simulation purposes, where the environment provides the stage setting for incidents and actions of trainees.

In the experiment discussed here, we studied the effects of dynamic visual and auditory elements on the appraisal of an environment, and on the response of the users, in a serious game: Levee Patroller [2]. These elements are often sparingly, or not at all, applied in 3D models due to costs of implementation and unfamiliarity with the effects on the viewer. Human environmental experience is however multi-sensory, so auditory and motional attributes of a setting, such as wind and waves, are environmental elements which should be included in the representation [3].

The increase in the use of game engines to build virtual environments, offering easy implementation of dynamics and sounds, raises questions about the effect of these visual and auditory elements on the perception and appraisal of the user. Our study thus concerns the so-called incremental validity of virtual environments, by assessing to what extent adding an extra sensory channel to the environment increases the amount of information communication and enhances the representational validity of the environment [4]. Although we focus on training environments, the results are relevant for visualizations for other purposes.

2. Background

3D models used for training and serious games, vary from simple and generic environments that supply a background when the focus of the training is for instance on complex cognitive or communicative tasks; to detailed verisimilar environments when elements in the environment are of importance for the goal of the training. Levee Patroller is an example of this second type. The serious game is developed by GeoDelft (now
Deltares) and Delft University of Technology using the Unreal Engine 2 Runtime game engine, as a training instrument for levee patrollers [2]. Levee (or dike) patrollers inspect levees at regular times, especially in situations when danger or damage may occur. Their task is to recognize failure mechanisms in an early stage and communicate relevant findings to the central field office. Practicing these skills in reality is difficult, as levee failures are quite rare. A serious game not only facilitates this but can also show failures of different kinds and severity, and in a variety of adverse weather circumstances which may limit visibility.

The validity of the virtual environment is presumed to be important for the training effectiveness. In the Levee Patroller, the lifelike representation of the failure mechanisms is essential. Secondly, the game environment with low-lying land, canals, and levees, and the weather conditions, must be valid to inform the trainee of the relevant geographical and meteorological circumstances. In the game, strong wind and heavy rain are suggested, which contribute to the danger of the situation. Thirdly, in reality the environment and events that occur, may affect the emotional state of the levee patroller and consequently his or her behaviour and performance.

Research in the area of computer graphics is mainly aimed at increasing visual realism. The effect of these realistically looking environments on the viewer, as compared to real environments, has been studied in several experiments. They reveal that the affective appraisals of viewers in reality and in the virtual environment show similarities as well as discrepancies (e.g. [5]) but the underlying reasons and mechanisms for these remain largely unclear.

Affective appraisals are judgments concerning the capacity of the appraised objects, for instance our environment, to alter an individuals’ mood, expressed in terms such as pleasant, repulsive, attractive etc. [6]. The affective appraisal of our environment is important because it continually, but often unconsciously, modifies our emotions, mood and behaviour. Many characteristics of the 3D model, the display medium and the viewer may influence the appraisal of the modeled environment. In 3D environments, sound is often lacking, although its importance is obvious from a large number of studies. Auditory background noises and sound events are essential to establish a feeling of contact with and presence in an environment [7-11]. Sound makes the environment come alive, and envelopes the user, thereby enhancing her involvement [12].

Another obvious characteristic, imposed by restrictions of hardware, software and by the required effort in modeling, is the static appearance of 3D environments, where the only movement is generally the consequence of navigation by the user. Sometimes dynamic textures are used to represent water and clouds, thus increasing the temporal variation in the scene. However, in most cases environmental elements are depicted as static. The environments thus lack the subtle movements that are characteristic for a real environment, such as branches moving in the wind, birds, cars and trains passing in the distance. In reality, dynamic features in a polder landscape are very important indications for the weather circumstances and the assessment of the risk of levee failures.

Movement is often accompanied by sound, and may be suggested by sound. Adding sounds to a 3D environment may enhance the effect of the visual dynamic elements, or compensate for their absence or perhaps rather crude representation.

By adding dynamic and auditory elements to Levee Patroller we may thus increase the validity of the environment, influence the emotional response of the trainee, and increase the effectiveness of the training.

3. Research Methodology

3.1. Manipulations

For the experiment a small area of the polder landscape of the Levee Patroller was selected, containing three different failure mechanisms. Four versions (experimental conditions) were created:

1. static, no sound,
2. static, with sound,
3. dynamic, no sound,
4. dynamic, with sound.

![Figure 1. Screenshot of the dynamic versions (3 and 4)](image)
In the first and second versions, some dynamic elements that were already in the game, were retained: raindrops, clouds, water surfaces, the failure mechanisms, and a meadow gate that opens on approach.

The dynamic visual effects that were added in versions 3 and 4 were: lightning, moving trees, more and stronger waves, seagulls, sheep, passing cars, a boat, a sinking dinghy and a street lamp pole that falls over in the storm.

To versions 2 and 4 sounds were added: a continuous soundtrack of rain, strong wind and thunder, and positioned sounds for the animals, and the events pertaining to the failure mechanisms.

All versions end with a dramatic break of the levee.

### 3.2. Participants

Participants were 55 Dutch residents, 27 males, 28 females. They can be divided in a group of young (18 in the range of 18-27 years old) and older participants (37 in the range of 41-81 years old). After removal of 5 participants who experienced problems with navigation, the average age was 44.7 years, with a standard deviation of 18.5.

### 3.3. Equipment

The experiments were performed on a Dell Dimension XPS-710 Dual Core computer, equipped with a Dell 19” monitor. A standard keyboard and mouse were used for navigation. For the versions with sound, a Sennheiser EH 150 headphone was provided.

### 3.4. Materials and procedure

We used a number of scales and questionnaires to obtain an overview of several interrelated aspects of the response of the participants. The fantasy proneness of participants was rated through five questions, which were inspired by the Creative Experience Questionnaire [13].

The pleasure and arousal score on the Self-Assessment Manikin (SAM; [14]) was obtained before and directly after the game play. During the game two facial muscles were monitored. The tension of the corrugator (frown muscle) and the zygomatic muscle response (smile muscle) were measured with the Mobi and Kendall ECG electrodes (H124 SG).

The evaluation of the environment was obtained through the Russell and Pratt questionnaire [15]. The adjectives were translated into Dutch and checked by a native speaker.

The experience of weather conditions was assessed by nine adjectives, based on Stewart [16], and rated on a scale of one to ten. Questions were added about the perceived quality of the representation of the rain and wind, and the congruence of sound and visual representation.

Another questionnaire was developed for the six elements that Mallon and Webb [17] deducted for engagement, also using questions of the ITC-SOPI physical presence questionnaire [18].

In many serious games the experience of fun by the trainee is an important element. Fun, clarity of the assignment and overall beauty of the game were therefore queried on a 5-point scale.

Using open questions we also asked which visual and audio items were most noticeable, and whether they contributed positively or negatively to the representation.

To increase the comprehension of the layout of the area during the experiment, we informed participants that they had to draw a map of the game environment and the important landmarks, after completing the game assignment.

On arrival, participants read and signed an informed consent and had a moment to relax. The pre-test questionnaire for general information and the creative experience questions were presented next, after which they rated the SAM for the first time. The experimenter explained the navigation and the goal of the game and placed the electrodes. For the versions with sound participants were asked to put on the headphone. They were allowed to place the headphone further to the back of the head if they found the sound volume uncomfortable (only a few did). The assignment was to find and mark three failure mechanisms and to draw a map of the inspected area after the game.
The duration of the game was 8.40 minutes. Finally, the second series of questionnaires was completed.

3.5. Hypothesis

The dynamic elements and sounds were added to compensate for information lacking in the representation of severe weather conditions. We therefore expected an increase in the perceived severity of the weather circumstances. We also expected to find a decrease in the perceived pleasantness, and an increase in the distressing and arousing qualities of the environment, in the manipulated versions. Sound was expected to have a stronger effect than visual dynamics, and the combination of both to have the strongest effect.

Visual dynamics and sounds were expected to increase the arousal of the participants and their appreciation of both the representation and the game. As for the performance in locating the failure mechanisms, the hypothesis was more tentative. On the one hand, the manipulations may increase engagement and therefore concentration and performance. On the other hand, visual and auditory effects may distract or even irritate participants, and obscure the indications of failure mechanisms, as in real life.

4. Results

The amount of data obtained is too large to discuss in full detail, so we focus on the appraisal of the environment and weather circumstances, and their correlations with other responses.

4.1. Appraisal of the environment

The addition of sound increases the arousing and distressing qualities of the environment. Table 1 shows the one-way ANOVA results. Post-hoc Tukey tests resulted in a significant difference on the dimension Gloomy between versions 1 and 4 (p< .01), and Relaxing (versions 1 and 2, and 2 and 3, both p< .05). Contrary to our expectations the enhanced environments are not considered less pleasant. However: the dynamic versions 3 and 4 are appreciated more than the static versions, which are perhaps considered lifeless and therefore less interesting. The post-hoc Tukey test shows a significant difference between versions 2 and 3, for the dimensions Pleasant (p< .05) as well as Unpleasant (p< .05). The addition of sound without visual dynamics (version 2) seems to have a negative effect on the appreciation of the environment. This may be an effect of the incongruity in the interface, where movement suggested by auditory effects is not corroborated visually and the environment is thus not ecologically valid [4].
Table 1. Mean scores on the dimensions of the Russell and Pratt scale

A number of individual adjectives of the Russell and Pratt scale (alive, hectic, panicky, boring, serene, restful, pleasant, pretty, dissatisfying, repulsive) differed significantly between versions. They illustrate that sound and dynamics especially reduce the lifeless and static nature of 3D environments. Version 2 scores lowest on the adjectives pleasant, pretty, and highest in dissatisfying.

<table>
<thead>
<tr>
<th>Item</th>
<th>F</th>
<th>Sign. ANOVA (p&lt;.05)</th>
<th>Version</th>
<th>Mean</th>
<th>Std. Dev.</th>
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<td>.001</td>
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<td>4.21</td>
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<td></td>
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<td>7.20</td>
<td>2.28</td>
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<td></td>
<td></td>
<td></td>
<td>3</td>
<td>6.22</td>
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<td></td>
<td></td>
<td>4</td>
<td>8.06</td>
<td>1.38</td>
</tr>
<tr>
<td>thunderstorm</td>
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<td>.000</td>
<td>1</td>
<td>0.95</td>
<td>1.39</td>
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<td></td>
<td></td>
<td>4</td>
<td>7.78</td>
<td>2.18</td>
</tr>
</tbody>
</table>

Table 2. Mean scores on weather items

4.3. Appreciation of the game and arousal

The effects of the visual dynamics and sounds on the appreciation of the game or the engagement of the participants did not reveal a consistent pattern. Dynamic effects did positively influence the involvement of the user, assessed in 5 questions: a difference was found between the static version (1) and the dynamic version (3) (F(1,25)= 2.21, p< .05). The dynamic conditions (3 and 4) had a higher evaluation of 0.5 points over the static conditions on a 5 point scale.

The arousal level assessed with the SAM, decreased during the course of the experiment in all four versions (t(49)= .01, p< .01). At the start of the experiment participants were probably somewhat nervous because of participating in the experiment. Valence increased in general (t(49)= .01, p< .01), but most for the versions with sound.

During the game a gradational increase of zygomatic muscle tension was found over all participants. The median of the tension before the game differs significantly from the median observed during the game play (t(42)= .00, p< .01) which indicates that the participants were more aroused during game play. No significant difference was found between the conditions [7, 19].

4.4 Performance

Participants did not perform better in the enhanced versions, possibly because the visual conspicuity of the failure mechanisms was similar and dominant in all versions. Navigation proficiency correlated positively with the number of failure mechanisms detected (r= .451, p< .01). The age of the participant correlated negatively with the ease of navigation (r= -.31, p< .01).
5. Conclusions and discussion

Visual dynamics and sounds may affect the viewer's response in two ways. Firstly, they may increase the fidelity and validity of the virtual environment, and increase the convincingness of the virtual environment. Secondly, they may increase the attractiveness of the game environment or the representation itself, to which the user may respond with for instance surprise or joy.

Events in a scenario that may affect the actions of a trainee in a serious game must be modeled in a convincing and verisimilar way: weather conditions may for instance influence the decisions of levee patrollers, but also of fire commanders. The results of our experiment show that sounds and visual dynamic features can effectively be used to convey certain severe weather conditions in a 3D environment, and may influence the affective qualities of the environment. We found that sounds were appreciated most for their convincingness in representing storm. Sounds and visual dynamic features can therefore enhance the validity of 3D-models of the built and natural environment when used for training as well as assessment, in for instance landscape and urban planning. This experiment confirmed earlier findings that auditory events, that are not accompanied by visual dynamics, may confuse the viewer [4]. It also agrees with previous reports that the expectation evoked by strong visual cues makes accompanying congruent sounds so highly expected that they merely confirm but do not further enhance the appreciation of the environment [20, 21]. This is probably also the reason why minimal sound effects based upon convention, expectation and caricature are so effective in eliciting immersive effects in movies and games [22, 23]. These findings may be relevant for training applications, where the fidelity of the environment may be important to achieve a convincing training scenario, thereby increasing the involvement of the trainee and possibly the transfer of training.

Secondly, visual dynamics and sounds may increase the liveliness and attractiveness of virtual environments. This is of course the purpose of advanced enhancements in game engines, such as CryENGINE2, where for instance vegetation and water surfaces are dynamic. They influence the emotional response of the viewer to the environment, regardless of their fidelity. This may be a useful means to increase the engagement of the viewer and eventually the impact of the training [24]. Influencing the emotional response of the trainee in serious games and training applications is a very valuable means to motivate trainees and to prepare the trainee to perform in a diversity of circumstances. Abundant evidence from research on films and games indicate that dynamic features [25] and sound [26, 27] can indeed be used to influence the arousal and valence level of the trainee.

Results of this experiment suggest that although sound and visual dynamics in the simulated environment do have a modest influence on some aspects of engagement, other game elements and user characteristics probably play a more important role.

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References


