Gaming at the dentist's – serious game design for pain and discomfort distraction

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Abstract. Virtual reality (VR) techniques have proved effective in distracting patients from perceived pain in a variety of studies. These results, partly due to the visual impact and immersion achieved, encourage investigating the purposeful design of games for deployment in a variety of dentist treatments. In fact, a large group of patients, particularly youngsters, experience a strong resistance or even aversion to visiting a dentist's practice, often due to previous distressing and painful experiences. We argue that, to solve such situations, distracting a patient with just an attractive virtual environment is less efficient than with an interactive game expressly designed for this context and purpose. This paper presents the first results of a pilot project in this direction. We discuss the various requirements gathered throughout the project, and describe several technological challenges, involving e.g. user experience, interaction, content, graphics, which we faced throughout the game design and development phases. Although the project is still ongoing, the preliminary results of the prototype game evaluation in a controlled environment were very encouraging.

Keywords: serious games, dental treatment, pain distraction, virtual reality

1 Introduction

Virtual reality (VR) techniques have often been deployed with considerable success as a method for distracting patients and reducing their perceived pain, as well as in helping overcome anxiety [4, 2]. Several studies report on the successful application of VR distraction to reduce pain associated with e.g. cancer-related treatment [10], intravenous placement [5], and burn injuries [8].

Specialists point out as main reasons for this success the visual impact of a virtual world, the freedom of navigation, the high-degree of interactivity, and the consequent high-level of immersion experienced. In short, a patient can get so deeply immersed when experiencing the virtual world that much less attention will be spent in processing the pain being suffered.

There have been various experiments on exposing patients to VR environments during dental treatments [11]. For example, a study concluded that VR immersion had been very successful in increasing the "amount of attention drawn away from the 'real world', allowing patients to tolerate painful dental procedures" [7]. More recently, a randomized controlled trial showed that "virtual reality eyeglasses can successfully decrease pain perception during dental treatment" [1]. In the commercial product Isla Calma, the patient could even have some active roles, as e.g. picking collectibles or making choices [3]. However, these simple actions are rather isolated and unlikely to keep the patient's mind busy for a contiguous period. Moreover, the VR environment and experience they describe, no matter how attractive and immersive, were designed for generic pain distraction, not for specific treatments in the context of a dental clinic. This has a number of disadvantages, as we will see in the next section.

Dental clinic patients with a critical discomfort often develop a mild anxiety of being exposed to the pain associated with even routine treatments. This discomfort, if not overcome by children, might lead to aversion or even avoidance of any treatment at all, which would only increase the damage in the near future.

How anyone becomes afraid of a dentist, is best explained by Pavlov's theory. If, for example, you experience pain while drilling, you learn that drilling will hurt. The brain remembers this and, with the next dental drilling experience, one is reminded of the pain and that makes you anxious. In other words, at a next treatment one is afraid because of the fear that it will hurt. This is called classical conditioning.

Fortunately, both this anxiety and the associated pain itself can be overcome by a proper use of distraction. We believe that, to solve such situations, distracting dental patients with just an attractive virtual environment is less efficient than with an interactive game expressly designed for these purposes. This paper reports on our pilot project in that direction. For this, we set up an interdisciplinary research team consisting of dentists, computer scientists, game designers, and user experience experts. As far as we know, this is the first pain distraction game purposefully designed from the outset for deployment in a dentist context.

In this paper, we first discuss the various requirements gathered throughout the project. We then describe several technological challenges, involving e.g. user experience, interaction, graphics, which we faced throughout the game development phase. We also discuss the results of the preliminary game evaluation in a controlled environment and, finally, we draw a few conclusions.

2 Requirements

In this section, we elaborate on the two main types of requirements that we collected at the beginning of this project, and drove the whole game design and development process. First, from the dentist specialists in our team, we gathered a variety of requirements from the perspective of their work circumstances and of the treatments for which the game could be deployed. Second, from a game designer's perspective, we identified a number of requirements that greatly influence the game genre, the gameplay and its pace, the type of content, etc. In this section, we summarize both types of requirements and indicate how we got along with them. This exercise plays a crucial role in clarifying how to solve the

various conflicts among the different requirements and domains involved. In this task, we applied recent serious game design methodologies [6].

2.1 Dentist domain

Regarding audio-visual technology, there are two main constraints to be concerned about: on the one hand, the visualization should not be hindered by the dentist at work; on the other hand, the dentist should be able to stay in permanent contact with the patient, e.g. to ask questions and receive quick and intelligible answers. In particular, the use of music or any other game sounds should never cause the patient to lose contact with the dentist. These constraints quickly converge to the deployment of (some type of) VR goggles. In that case, an important factor is the size and the weight of the goggles. Working in the mouth of the patient requires a certain clearance area for treatment: the goggles may not interfere with it, nor limit the operation space. Wires and cables should in general be avoided, both on the floor and around the patient's head, in order to avoid any accidents, and to facilitate manipulating dental instruments in the mouth without any hindrance. So a wireless system should be preferred. Furthermore, whatever the setup, the system should not hinder nor burden dental personnel in any way: it should be easy to set up and technically not complicated.

Regardless of the kind of game controller, its use should be very simple, requiring e.g. only one or two controls, and intuitive. The bottom line is that the patient has to quickly get used to it without ever needing to look down at the controller, when lying in the dental chair. To facilitate this, the possibility should be considered of having (new) patients start playing the game outside the dental chair, for instance in the waiting room, so that they get prior experience with the game, controller actions, etc.

Regarding safety, additional measures may be required due to the co-location of electronic cables, the use of water and of rotating instruments with water cooling. Furthermore, disinfection of all devices used for the game (e.g. goggles and controller) will have to be performed using swabs with alcohol, as usual in dental clinics. So device materials must be resistant for this kind of fluids.

Due to the large variety of dental treatments, the duration of the game would better be flexibly adjustable by the dentist; so ideally, the player will, say, neither 'finish all levels' too early nor ask to continue a while after the dentist is done with the treatment. However, this should be achieved without damaging the challenge level with abrupt variations, so that the game will remain challenging for both short and long treatments, without leaving a feeling of frustration when it is 'game over'.

Regarding the kind of game environment and actions, the player should always feel comfortable and relaxed, without unexpected, startling or violent events. In particular, it is important to avoid any sudden movements of the patient, especially of their heads, while lying on the chair. For this reason, for example, we consider that head tracking should never be used in combination with the VR goggles in a dental clinic setting like ours, as it would encourage moving the head around, with all sorts of associated risks.

2.2 Game design domain

For the game design process, the two main drivers identified are the constraints just mentioned above: *relaxation* of the player, and the *physical setup* at the dental clinic. All other aspects, including *gameplay*, although important, are secondary.

Relaxation: early during our design process, we felt that the key to relaxation would be immersion. With this, we mean offering players a compelling presentation, including visuals and narrative, that instantly draws them in. Keeping in mind the target audience for our initial pilot project (10 to 16 year olds), we investigated a simple yet powerful concept: players would navigate their airship through a series of caverns. Later, as development had already started, we adapted the theme to a submarine navigating through underwater caves.

Physical setup: since players should move as little as possible during the procedure, we chose to use VR goggles and a wireless controller. The game is controlled using only the left joystick, and therefore should be easy to 'pick-up and play'. Furthermore, we expect that giving players something tangible to hold in their hands helps to distract them as well.

Gameplay: the experience features a balanced mix between player control (freely moving the submarine in all directions) and computer-driven events (gravity, steady forward panning of the animated camera), forcing players to actively keep up. Within the game environment, seen from the side, players must avoid hitting the cavern ceiling and floor, as well as evade hostile objects floating around in the water. However, they may also pick up certain items to score points, offering moment-to-movement mini-goals, and requiring from the player proper risk/ reward considerations.

Currently, to increase accessibility as well as replayability of the game, we added two difficulty levels. On easy mode, most players should have little trouble reaching the end of a level. On hard mode, extra obstacles offer bigger challenges. In our upcoming test sessions, it will be interesting to investigate to which extent this additional challenge will be beneficial or detrimental to relaxation and immersion.

Eventually, for final deployment, we intend to implement high-scores into the game, so that players may compare their achievements with each other. Such a sound competition might even stimulate them to try and improve their results, increasing the longevity of the game within the dental clinic, as well as keeping players distracted for longer periods of time.

3 Prototype development and evaluation

The development of our first prototype followed the requirements gathered from the dentist domain, and their corresponding interpretation from a serious gaming design perspective, as introduced in the previous section. We consider the content, the learning curve, and the user interaction among the key points for our game implementation, to which special attention was given in order to fulfill all the above requirements.

Starting from the content, our focus on player's immersion led us to the design and incorporation of engaging graphics such as the underwater environment and the submarine itself, as shown in Figure 1. Moreover, we made a selection of comforting colors featuring shades of blue, which reinforces the other requirement of maintaining the player calm and relaxed.

Concerning the learning curve, the submarine theme was found to be very suitable, as it turns out that most people rather intuitively can anticipate how a submarine behaves under water, subject to a constant gravity force. Although intuitive, there is still ample room for learning since, due to a careful level design, the navigation in increasingly narrow caves is still hard to master. This makes the game more intriguing and challenging for the player.

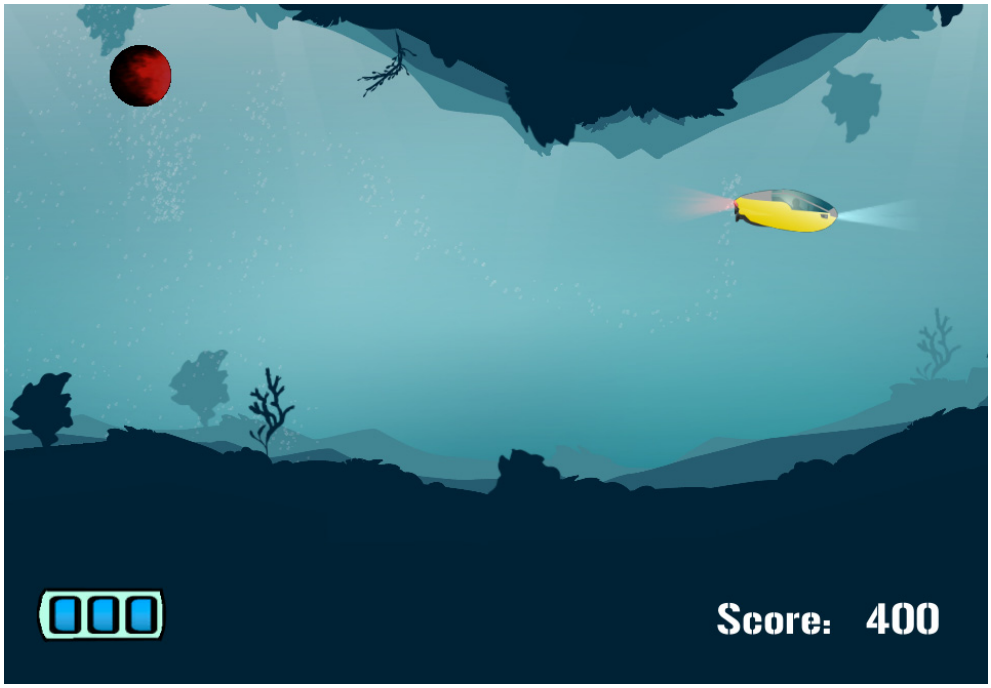

Fig. 1. Screenshot of the first game level

The requirements described in Section 2 also set new challenges in terms of human-computer interaction. As mentioned before, they almost necessarily lead to the use of some light VR eyewear and a wireless game controller. In our current prototype, the equipment setup consists of the following components:

Display technology: we have been using Vuzix 1200VR goggles, but without making any use of its head tracking nor of its stereo imaging for the reasons explained in Section 2. This eyewear reaches a resolution of 1280 x 720, and provides a relatively dark environment without total enclosure of the users sight. This effectively helps patients keep focused on the gameplay, and avoids distractions from the surrounding environments but without depriving them from the crucial audio-visual perception of, and communication with, the dentist.

Controller: the game is played with a wireless XBox 360 controller. Only the left stick is being used and has been programmed to carry out the submarine's movement in all four directions.

In order to make the game more interactive and immersive we integrated a variety of visual elements and audio effects; see Figure 1. A life bar is used to display the submarine's health, represented by three bars on the lower left corner. The health is calculated based on the rewards retrieved by the submarine and on the damage caused by hostile objects, like the red ball shown. Additionally, a scoring system based on the number of rewards is permanently displayed on the lower right corner. Other visual effects include small air bubbles that follow the movement of the submarine, and moving air bubbles around hostile objects (e.g. the red balls). In order to keep the user aware of successful actions (e.g. retrieval of a reward item), we have sporadically added some subtle sound effects. In the

future, we plan to investigate whether other audio forms could potentially enhance the immersion without hindering communication.

Our prototype was developed using the Unity game engine, which very much facilitated the integration of components like the environment, the navigation, the graphics and audio effects, as well as the artificial intelligence and scoring mechanisms. In addition, Unity permits running the game both as a standalone executable and online, on the browser, by means of the Unity Web player.

We made some preliminary tests of the current prototype game in a controlled environment, to have an early sense of how it was performing relative to the two crucial issues of player relaxation and physical setup. These resulted in very encouraging outcomes.

Fig. 2. Preliminary evaluation tests during STEM Girls Day

The occasion was given by a STEM (Science, Technology, Engineering, Mathematics) demo day, nationally organized for school girls, aged 8 to 15. For this, we set up a booth featuring a deep-leaning chair, simulating the dentist chair, the VR goggles and controller, and, of course, the computer running the game, with a large screen where all bystanders could follow the 'patient' playing, while lying on the chair; see Figure 2. Sitting beside the chair was the dentist, who talked to the playing child, putting questions and giving various instructions, 'as if' a real treatment was going on. As mentioned above, using these goggles the child was able to play the game as well as perceive the dentist's presence.

The game environment was considered attractive and relaxing, and the gameplay, very successful: all children were eager to get to the next level and were very concentrated on getting higher scores. Nevertheless, in all cases, it was remarkably surprising how easy the communication was between the dentist and the children as they played on the chair. For example, they promptly followed commands for 'opening the mouth wider', 'turning their head aside', etc. whilst continuing to play the game, without any perceptible disruption of

the gameplay. Even more, outside those explicit dentist commands, it was noteworthy that all children held their heads very still throughout the whole session. We mainly attribute this to the fact that our game features a steady, slow-paced side scrolling.

Eventually, all children were quite enthusiastic about the game and wanted it to be available at their own dentist. They also commented, for example, that 'they now had something cool to do in the dentist chair' and that 'going to the dentist would become a lot more fun'.

4 Conclusions

Many patients, particularly youngsters, experience a strong resistance, at times, utter aversion, to visiting a dentist's clinic, often due to previous distressing and painful experiences. We pose that distracting a patient with an interactive game expressly designed for this context can be very helpful and effective to solve those and similar situations. We discussed the first results of a project in this direction, and identified a variety of requirements, from both the dentist's and the serious game designer's point of view.

Various technological challenges, which we faced throughout the game design and development phases, were discussed and solved, involving e.g. user experience, interaction, content, and graphics. For example, we concluded that slow-paced, steady side scrolling is a very appropriate and successful game progression mechanism that very well fits our dental clinic setting requirements.

We expect that a compelling gameplay, with its calm but steady attention focus, should help to better distract patients from the dental treatment and its associated pain. Even more, for long dental treatments (e.g. root canal or orthodontic treatments, which can easily last 30-60 minutes), an immersive game like this, is very likely to improve the patient's sense of elapsing time.

Still, we argue that there is no pain distraction game, VR environment or system that is 'good-for-all-situations', due to the large variety of circumstances and constraints across specific domains. For example, fully enclosing goggles with head tracking have the undesired consequence, for dental treatments, of inducing patients to unpredictably turn their head, to look around in the environment. From our preliminary project experience and prototype evaluation, we concluded that the best approach is a careful, ad-hoc game design, taking into account problem and domain-specific constraints and requirements.

Among the next steps in our project, we will, very soon now, perform actual test sessions in a dental clinic, followed by the investigation of adaptive gameplay mechanisms, in order to strengthen the flexibility of gameplay duration and enlarge the target public of this game [9].

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