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Outline of an empirical study on the effects of emotions on strategic behavior in virtual emergencies

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Abstract. The applicability of appropriate coping strategies is important in emergencies or traumatic experiences such as car accidents or human violence. In this context, emotion regulation and decision making are relevant. However, research on human reactions to traumatic experiences is very challenging and most existing research uses retrospective assessments of these variables of interest. Thus, we are currently developing and evaluating novel methods to investigate human behavior in cases of emergency. Virtual reality scenarios of emergencies are employed to enable an immersive interactive engagement (e.g., dealing with fire inside a building) based on the modification of Valve's popular Source™ 2007 game engine.
This paper presents our ongoing research project, which aims at the empirical investigation of human strategic behavior under the influence of emotions while having to cope with virtual emergencies.

Keywords: Coping, virtual reality, empirical study, head-mounted display

1 Introduction

The necessity of appropriate coping strategies for emergency situations has become apparent to the public by catastrophes such as the ICE accident in Enschede 1998 or terror attacks like the one on the World Trade Center in 2001. Also in common place emergencies or traumatic experiences such as car accidents or human violence coping strategies, comprising of emotion regulation and decision making, are relevant. In general, research on human reactions to traumatic experiences is very challenging. Thus, we aim to develop and evaluate novel means to investigate human behavior in cases of emergency.

In order to let people engage in emergency situations, we make use of state-of-the-art Virtual Reality (VR) equipment. At the same time we measure physiological indices online and relate them with questionnaire results with respect to the emotional impact of the emergency scenario presented interactively.

Our project faces the following three challenges arising from our aim to evoke natural emotional effects in emergency situations that can also be assessed at runtime:

- The VR hardware technology has to allow for a high degree of "immersion" (Slater & Willbur, 1997) as it is a mandatory prerequisite for achieving "presence", i.e. a user's strong feeling of "being there" in the virtual world. At the same time, it needs to be compatible with the presentation software and should be affordable in price, because the system is planned to be used to train coping strategies in the public later on.
- The VR software framework has to permit the creation and simulation of detailed, high-quality, interactive scenarios in order to allow for high "plausibility" (Rovira, Swapp, Spanlang, & Slater, 2009). In this respect, simulated, physically correct movements of objects are as important as believable and situation-appropriate behaviors of virtual characters.
- In order to assess the emotional effects of being immersed in virtual emergencies, a number of psychological measures need to be applied both on the level of subjective report and on the physiological level. The latter will be used during exposure, whereas the former can only be applied before and after the VR experience, because its assessment is based on questionnaires.

The paper is organized as follows. First, we give an overview of related work on VR research in general and the use of VR in the context of applied research on emotions in particular. This is followed by an outline of the decisions we had to take in order to achieve the highest possible degree of immersive VR experience using relatively inexpensive and flexible of-the-shelf hard- and software components in light of the interdisciplinary research goal. Section 4 will describe the overall design of an ongoing empirical study, before in Section 5 preliminary conclusions will be drawn.

2 Related Work

Over the last ten years VR technology has been used, for example, to train surgeons (Seymour, 2008), to treat posttraumatic stress disorder (PTSD) in veterans of the Iraq war (Reger & Gahm, 2008; Kenny, Parsons, Gratch, & Rizzo, 2008), or as a means to evaluate emotion simulation architectures driving virtual humans (Becker-Asano & Wachsmuth, 2010; Gratch & Marsella, 2005). Furthermore, a VR setup has evoked similar responses to violent incidents in human observers as can be expected in real world situations (Rovira, Swapp, Spanlang, & Slater, 2009) given that a high degree of plausibility could be achieved and maintained.

All these applications are realized with different simulation software, ranging from game engines such as Epic's Unreal Tournament (Reger & Gahm, 2008; Kenny, Parsons, Gratch, & Rizzo, 2008; Gratch & Marsella, 2005) to a number of custom made installations (Dunkin, Adrales, Apelgren, & Mellinger, 2007; Becker-Asano & Wachsmuth, 2010) with proprietary software components. They are combined with different display technologies such as panoramic, auto-stereoscopic, or head-mounted displays (HMDs), or even CAVEs (Brooks, 1999). Notably, according to Slater (2009) one can, in principle, simulate a CAVE with a (head-tracked) HMD and a CAVE, in turn, enables one to simulate a panoramic screen. Thus, if the field-of-view of an HMD is sufficiently big and head movements of its user are taken into account, an HMD can be considered the best choice, because it is also least expensive and easiest to transport. Of course, the weight of the HMD and the according discomfort of wearing it over a longer period of time can be considered a clear disadvantage of such technology.

The VR-related aspects of a project for PTSD treatment are meant to teach the patient “coping skills” (Riva, et al., 2010) through virtual exposure, similarly to our project goal. For an empirical study on the link between presence and emotions Riva and colleagues (2007) used an HMD with head-tracking and a joystick for navigation. They successfully induced an anxious mood in participants only by systematically changing visual and auditory components of a virtual park scenery.

In applied research on emotions with Virtual Humans coping is mostly understood as an agent’s ability to deal with its emotions in either a problem-focused or an emotion-focused way (Marsella & Gratch, 2009). In this sense, emotions as a product of situation appraisal either cause behavioral change or a process of (internal) reappraisal. As for now, we are merely interested in assessing the behavioral changes caused by fearful emotions, which we are hopefully able to induce in our participants by means of our newly developed VR setup.

3 Outline of the Research Project

3.1 Research Goal

We aim to develop novel technological means to assess emotional reactions of people online while they are interactively exposed to potentially life-threatening emergencies. In a second step, we would like to use this technology to train coping strategies in these emergencies.

At first, however, it needs to be assured that the emotions evoked by employing our technical setup are not only similar to, but also similarly intense as those emotions that can be expected to arise in similar real world emergencies. In the worst case, participants will simply treat the VR situation as if they were playing a computer game, in which their actions and corresponding emotions might be driven by the playful aim to explore the artificial world and its rules, rather than to cope with the emergency in a realistic way. Previous research on fire simulation in VR and subjects’ behaviors (Smith & Trenholme, 2009) has shown that, first, the type of interface the user is provided with, and, second, his or her previous experience with computer games seems to have major impact on this undesired effect. As we opted for the rather uncommon use of a tracked HMD in combination with a joystick controller, even experienced players of computer games will most likely not treat our setup similarly to a computer game.

Furthermore, our setup allows us to investigate, how strategic behavior might change under the influence of emotions. Accordingly, as a first step we decided to test, if our VR scenario has a similar emotional effect on participants as a video clip, which has already been evaluated to induce fear. Therefore, we designed an empirical study with one group of participants, who watched a fear-inducing movie clip before entering the VR scenario, and control group that watched a neutral video instead.

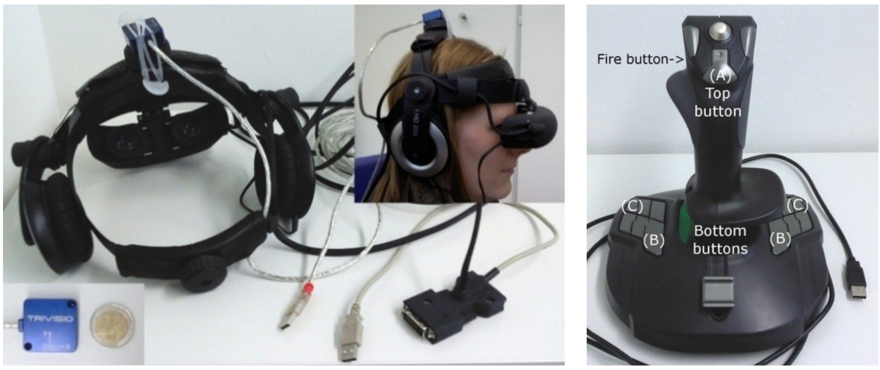

Fig. 1. (left) TriVisio's "VRVision" HMD with the "Colibri" tracker (down left) attached; (right) The "Thrustmaster T-16000M" joystick for navigating the virtual emergency scenario.

Fig. 2. (left) An example of the complete setup; (middle) The experiment room with HMD, joystick, physiological sensors, fan, and desktop monitor; (right) The "VarioPort" biometrical device with sensors for skin conductance, ECG, finger pulse, and chest measurement, plus remote marker buttons

3.2 Hardware Setup

At first, the VR-related setup will be described in detail, before also the physiological devices are explained.

Virtual Reality Setup. For the immersive setup we opted for Trivisio's "VRvision HMD" (Trivisio), which features two SVGA AMLCD 800x600 color displays with 24 bit color depth, 60 Hz video frame rate, and a field of view of 42° diagonally and 25° vertically, cp. Fig. 1. The HMD is powered via USB, by which a pair of built in Sennheiser HD 205 headphones are connected to the PC as well. An ATI Sapphire Radeon 5870 together with an Intel Core-i5-760 CPU drives the HMD via its two distinct DVI inputs making use of the iZ3D driver under Windows 7 (64bit). A USB-powered "Colibri" tracker—mounted on top of the HMD—provides information on the user's head movements including yaw and pitch, which allow the user to look around in the virtual world.

Table 1. Joystick configuration for moving in and interacting with the virtual environment

In-game movement / action	Joystick configuration
Forward / backward	Push / pull (pitch)
Turn	Turn handle (yaw)
Side step	Tilt left / right (roll)
Use (pick up / release / open)	Top button
Duck	Base button
Throw object / use tool	Fire button (front)

In 3D first-person computer games, such as the one we modified, the default user navigation is achieved by means of keyboard and mouse and a considerable amount of training is needed to get accustomed to it. As our participants can be expected to have diverging levels of gaming experience, and, thus, to avoid that experienced players might treat the setup similar to a computer game, we decided to implement a rather unusual navigation method by means of a Thrustmaster T-16000M joystick; cp. Fig. 1, right, and Table 1. This joystick can easily be adjusted for left-handed use.

The user can move forward and backward through the virtual world by pushing and pulling the joysticks handle, respectively (cf. Table 1 and Fig. 2, left). By leaning the handle left or right the user can step sideways, whereas turning the handle itself slightly to the left or right makes the user turn accordingly inside the virtual world. Finally, by pressing and holding “base button B” the user can duck to crouch below an obstacle, for example. As soon as “base button B” is released, the user returns to a standing position in the VR world again. In addition, two more of the joystick’s buttons are programed to let the user interact with the virtual world. “Top button A” lets the user pick up an object (any small physical object, which does not qualify as a tool) or a tool (in terms of the game engine also called a “weapon”), which he or she is looking at. While holding an object, pressing “top button A” again will result in dropping the object. While holding a tool, however, the user can still open and close doors or push buttons (such as for calling an elevator) with “top button A” the same way as without holding any object or tool in his or her hands. By pressing the “fire button” on the front of the joystick, the user either throws an object or uses the tool he or she is holding. For example, a spray can is implemented as a tool, which emits white paint when being used. If he or she wants to throw a tool away, the user can press “base button C.”

Although the participants wear an HMD (cp. Fig. 2, left), they were also provided with a standard desktop monitor (cp. Fig. 2, middle) for online questionnaire assessment before, between, and after the experimental sessions. The electrical fan (cp. Fig. 2, middle) was used to distribute artificial smell of burning fire at a certain moment during the experiment.

Physiological Sensors Setup. The following physiological indices (cp. Fig. 2, right) are taken from each participant using a “VarioPort” biometrical device in order to assess physiological arousal whilst participants are in the virtual world:

- Skin conductivity taken from the non-dominant hand's palm
- Heart rate variability, i.e. the variation in beat-to-beat intervals in the heart rate signals, based on the electrocardiogram recorded from the participant's chest
- Breath rate variability derived from chest measurement at a high and a low position on the participants chest

These sensors are recorded in parallel for later analysis. In order to relate the physiological indices with certain events in the virtual emergency, a number of markers are set manually by the experimenter from a remote location, which is separated from the participant by a black curtain during the experiment.

3.3 Software Setup

A large number of game engines allow for rapid prototyping of virtual worlds that feature both high-level graphical as well as interactive realism. In choosing Valve's Source™ Engine (Valve Corporation) as our software framework we follow the conclusions provided by Smith and Trenholme (2009). This game engine exists in three versions, two of which are available as open source, namely Source 2006 and Source 2007. The newest 2007 engine version of the Software Development Kit (SDK) is included on the Orange Box edition of Valve's Half Life 2 computer game. A number of modifications are based on either the single- or multiplayer part of the source code. In at least one of them, namely "Missing Information" (Gabe), a fire extinguisher has been reactivated from an early, abandoned version of Half Life 2. This allows the player to extinguish a virtual fire by shooting white smoke at it.

To implement this project's virtual emergency scenario the source code of the Source™ 2007 engine had to be modified. In addition, an underground parking lot needed to be designed that features signs, doors, stairways, elevators, cars, and additional models such as a coke vendor machine to make it look most convincingly.[1]

4 Design of the Empirical Study

4.1 Overall Design

The overall design of our study can be split up into five parts (cp. Fig. 3):

1. Socio-demographical data and personality profiles as well as previous experience with computer games and VR technology are acquired through questionnaires. A five minute physio-baseline is recorded. A rating of felt fear, anger, shame, sadness, happiness, boredom, guilt, and tension is acquired on a ten point scale each ("EMO-Rating").
2. Participants are guided acoustically and visually through a training course, which starts at their own car in the parking lot and ends after exiting an elevator on the ground floor. This training allows them to get used to the interface and it is being followed by another rating of felt emotions, see above.

[1] Videos of this VR scenario can be found at http://bit.ly/pc7Ou6.

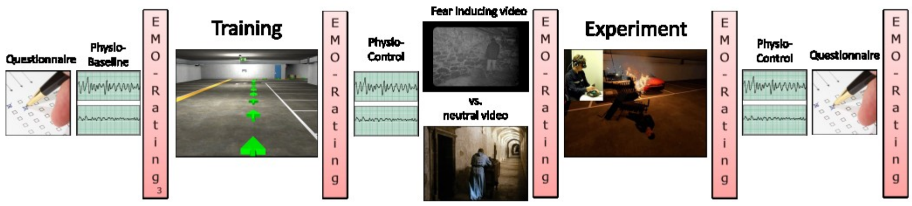

Fig. 3. Outline of the overall design of the empirical study

3. After a control of the physiological measurement the participant either watches a neutral video clip (control) or a fear inducing video clip (experimental manipulation). Both are around five minutes long and the latter is a clip taken from the movie "Blair Witch Project." Then the participants rate their feelings again.
4. The experimental session starts with the participant standing in front of the elevator on the ground floor inside the same virtual world as the one used for training in step two. They are instructed to go down to their red sports car and drive it out of the parking lot. They are also told to react adequately in any situation that they might get into. (For a more detailed description see Section 4.2.) After the VR experiment the participant has to rate his or her felt emotions again.
5. Finally, the physiological measurement is being controlled again and the participant is asked to fill another questionnaire and to report one last time on his or her felt emotions.

4.2 The VR Experiment

In the experimental session the participant is instructed to get back to his or her red sports car, which he or she was introduced to in the beginning of the training session.

First, the participant has to call the elevator and wait for it to arrive. Then, after pressing any of the elevator's buttons inside, the "P5" button is lit and the elevator starts moving down to level five accompanied by some machinery sounds. After the doors opened again, the participant has to step out of the elevator and open the blue door to get from the elevator room into the parking lot; cp. Fig. 4 (a).

While walking back in the direction of the red sports car, which is hidden behind one of the walls (cp. Fig. 4 (b)), the light configuration is the same as during the training session, i.e., all lights are on and the participant has a good overview of the parking lot. Suddenly, however, a loud noise is played together with some male scream and the lights in the parking lot are dimmed to nearly dark; cp. Fig. 4 (c).

If the participant does not give up on approaching the red sports car, he or she finds a male person lying beneath a number of heater elements, which seemingly prevent him from escaping the dangerous situation; cp. Fig. 4 (d). When approaching him, the injured person raises his head and shouts "help!" once, before fainting and stopping to move. In fact, the participant has no chance to help this person other than by extinguishing the fire behind him (cp. Fig. 4 (e)) and starting the alarm by pressing one of the emergency buttons; cp. Fig. 4 (f). The fire, however, can only be extinguished (cp. Fig. 4 (g)) after one of the fire extinguishers has been picked up from a wall; cp. Fig. 4 (f). While the fire is burning, the area of the emergency is

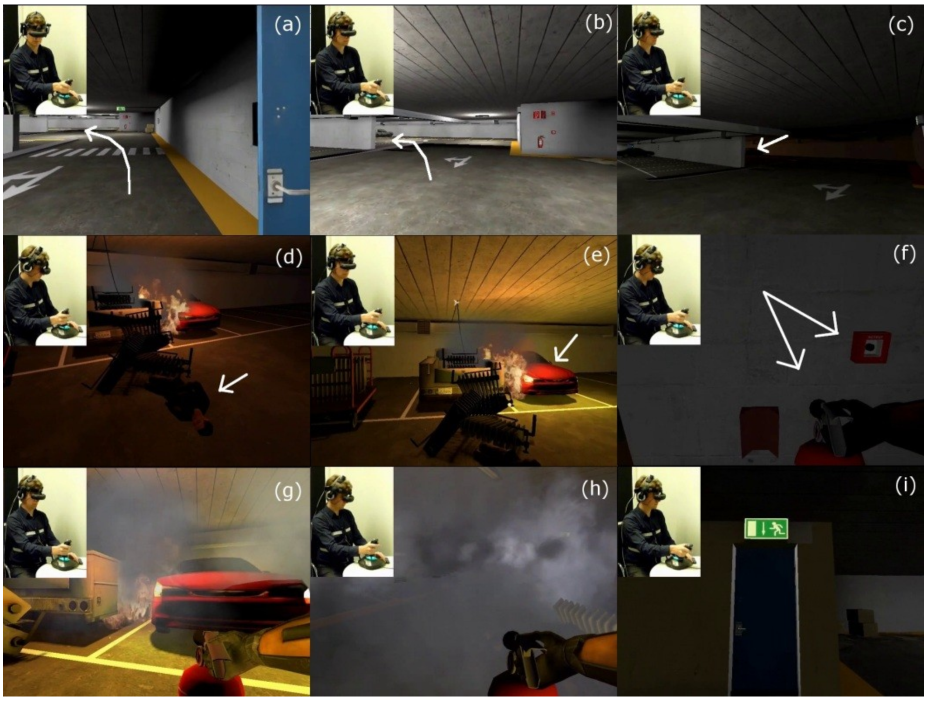

Fig. 4. An example run of an experimental session

gradually filling with smoke (cp. Fig. 4 (h)) making it not only increasingly more difficult for the participant to find his or her way out, but also more dangerous, because in a standing posture the smoke is programmed to have a negative health effect. This is made clear to the participant by periodically appearing red flashes on the screen together with different coughing sounds being played at the same time. Only by keeping in a kneeling posture the participant can avoid this negative effect. The experimental session ends when the participant either takes one of the emergency exits (cp. Fig 4 (i)), or a car exit, or calls the elevator.

5 Preliminary Results and Conclusions

At the time of writing, the data of 19 participants have been collected. Ten of them participated in the control condition (one male, nine female) and nine of them in the experimental condition (four male, five female). The time that participants stayed in the VR scenario were not significantly different (ctrl: 323 secs, STD 134 secs; exp.: 302 secs, STD 130 secs; two-tailed t-test (unequal variances): $p>0.73$, n.s.).

Table 2, however, reveals that a greater percentage of the nine participants, who had watched the fear inducing video, pressed the emergency button (78%) and extinguished the fire (78%) as compared to the control group participants (50%). Grouping the participants according to their resp. gender, however, shows that all five male participants took a fire extinguisher and extinguished the fire in contrast to only approx. half of all 14 female participants.

Table 2 Performance points and actions per experimental group

	points	call emerg.	take fire exting.	address person	exting. fire	take elevator	take stairs	take car exit
Exp. (9)	∅ 32	78%	89%	44%	78%	22%	67%	11%
Ctrl (10)	∅ 26	50%	50%	60%	50%	20%	70%	10%
f (14)	∅ 25	64%	57%	50%	50%	21%	71%	7%
m (5)	∅ 38	60%	100%	60%	100%	20%	60%	20%

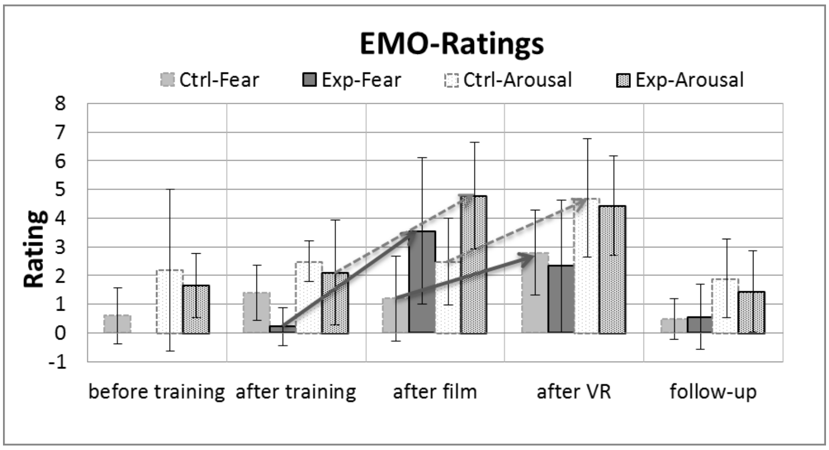

Fig. 5. Mean values with standard deviations for the emotion ratings of "fear" and "arousal" for 19 participants (nine experimental group and ten control group)

Figure 5 presents the means and standard deviations of the subjective ratings of felt "fear" and "arousal" after each part of the experiment. Concerning fear, as indicated by the two bold arrows in Fig. 5, our VR scenario seems to have a similar fear-inducing effect as the movie. The same holds for the increase of general arousal levels as can be derived from the positive slopes of both of the dashed arrows in Fig. 5. Notably, however, we also find that the high level of fear reached by the experimental group after watching the fear-inducing movie seems to diminish during the VR experiment. Thus, our preliminary conclusion is that we might not need to induce a fearful mood before the VR sessions. We are aware, however, that a higher number of participants is needed to consolidate this finding.

In the long run, we aim at a more detailed analysis that includes the personality questionnaire and physiological data, which will be analyzed in correlation with the trajectories of the participants in the VR emergency. Accordingly, we are confident that we can derive more meaningful conclusions in the future.

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References

Becker-Asano, C., & Wachsmuth, I. (2010). Affective computing with primary and secondary emotions in a virtual human. *Autonomous Agents and Multiagent Systems, 20*(1), pp. 32-49.

Brooks, F. (1999). What's real about virtual reality? *Computer Graphics and Applications*(19), pp. 16-27.

Dunkin, B., Adrales, G., Apelgren, K., & Mellinger, J. (2007). Surgical simulation: a current review. *Surgical Endoscopy, 21*, pp. 357-366.

Gabe. (n.d.). *Missing Information: Half Life 2 MOD*. Retrieved April 18, 2011, from http://www.love-tub.net/

Gratch, J., & Marsella, S. (2005). Evaluating a Computational Model of Emotion. *Autonomous Agents and Multi-Agent Systems, 1*(11), pp. 23-43.

Kenny, P., Parsons, T. D., Gratch, J., & Rizzo, A. A. (2008). Evaluation of Justina: A Virtual Patient with PTSD. *Intelligent Virtual Agents* (pp. 394-408). Tokyo: Springer.

Marsella, S. C., & Gratch, J. (2009). EMA: A process model of appraisal dynamics. *Cognitive Systems Research, 10*(1), pp. 70-90.

Reger, G. M., & Gahm, G. A. (2008). Virtual reality exposure therapy for active duty soldiers. *Journal of Clinical Psychology*(64), pp. 940-946.

Riva, G., Mantovani, F., Capideville, C. S., Preziosa, A., Morganti, F., Villani, D., et al. (2007). Affective Interactions Using Virtual Reality: The Link between Presence and Emotions. *CyberPsychology & Behavior*(1), pp. 45-56.

Riva, G., Raspelli, S., Algeri, D., Pallavicini, F., Gorini, A., Wiederhold, B. K., et al. (2010). Interreality in Practice: Bridging Virtual and Real Worlds in the Treatment of Posttraumatic Stress Disorders. *Cyberpsychology, Behavior, and Social Networking, 13*, pp. 55-65.

Rovira, A., Swapp, D., Spanlang, B., & Slater, M. (2009). The Use of Virtual Reality in the Study of People's Responses to Violent Incidents. *Frontiers in Behavioral Neuroscience, 59*(3), pp. 1-10.

Seymour, N. (2008). VR to OR: A Review of the Evidence that Virtual Reality Simulation Improves Operating Room Performance. *World Journal of Surgery, 32*, pp. 182-188.

Slater, M. (2009). Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*, pp. 3549-3557.

Slater, M., & Willbur, S. (1997). A Framework for Immersive Virtual Environments (FIVE) - Speculations on the role of presence in virtual environments. *Presence: Teleoperators and Virtual Environments, 6*(6), pp. 603-616.

Smith, S. P., & Trenholme, D. (2009). Rapid prototyping a virtual fire drill environment using computer game technology. *Fire safety journal, 44*(4), pp. 559-569.

Trivisio. (n.d.). *VRvision HMD product website*. (Trivisio) Retrieved February 17, 2011, from Trivisio Prototyping GmbH: http://www.trivisio.com/index.php/products/hmdnte/vrvision-hmd

Valve Corporation. (n.d.). *Half-Life 2*. Retrieved February 17, 2011, from http://www.valvesoftware.com/games/hl2.html