# The Future Impact of Immersive Virtual Reality Simulations on the Suburban Training Experience of Firefighters in Westchester, NY

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## Abstract

This paper describes a prototype of a firefighter training platform utilizing an immersive virtual reality environment. Advances in technology, with the adoption of virtual reality (VR) systems for training purposes, may provide learners with educational environments with life-like simulation interfaces. A prototype was created to simulate interactions a firefighter might experience in a fully immersive environment. The prototype was used to educate firefighters on the concept and survey them for feedback on the proposed learning environment. To achieve a fully immersive virtual reality, visual, tactile, auditory, olfactory and gustatory feedback was used. It was found that a fully immersive virtual reality environment would meet the needs of a successful multimedia design as regards cognition and motivation.

The prototype is available here (https://www.youtube.com/watch?v=Tyyxff__zbY)

Also available by searching YouTube.com for ‘ed tatton video 1’

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## Introduction:

Paid and volunteer firefighters in Westchester, NY currently are trained at the Fire Training Center located in Valhalla, NY. The facility contains three cement structures used to simulate burning buildings, dummies to represent bodies in need of extrication, and other equipment, including hoses and hydraulic rescue tools. Local firehouses commit to a monthly in-house training session where topics vary. Due to the operational cost of training at the Fire Training Center, an entire firehouse or two is involved in group training, even though this doesn't reflect real-world conditions. Drills are practiced in ideal conditions, with a lot of manpower, in cement block structures that may not burn in a realistic manner. A fully-immersive virtual reality environment was prototyped to see if it might reduce costs of training and provide localized realistic training for firefighters in environments reflecting incidents they will encounter while on the job.

## Background:

Current virtual reality (VR) systems are restricted by technological advances to remain in a semi-immersive state, they require head mounted or large screen displays and face a multitude of latency and processing power issues (LaValle, 2013). Virtual reality simulations used in educational environments may include some sensory feedback, most commonly visual, tactile and/or auditory feedback. As most early adopted technologies, there are plenty of advances needed before they become a valuable and affordable learning tool. Fantola and Giovanni (2014) conducted a blind study of surgical training for Urologists in two groups, a virtual reality environment group and a traditional box training group. The virtual reality training environment was not fully immersive and simply provided visual and tactile feedback. Fantola and Giovanni

(2014) found that a statistically significant difference had not been detected between the success rates of computer-aided simulation, and classical box training. Also in both groups, there was no statistically significant difference detected between gained motor skills.

The proposed fully immersive virtual reality environment would include visual, tactile, auditory, olfactory and gustatory feedback, with no latency and customizable training environments, providing a life-like experience for learners. Utilizing nanotechnology to connect with the central nervous system of learners, powerful computers of the future may be able to seamlessly interact back and forth between learners and the artificially created training environment (Big Think, 2011). This system will allow for safe, customizable environments to help mentally prepare firefighters for situations they may encounter in their local area.

## Research Questions:

Could the life-like experience within a fully immersive virtual reality training experience provide a superior learning environment for a consequence-driven training program? Once hardware is developed and the software is created, a fully immersive virtual reality environment could offer safe and viable alternatives to traditional firefighter training methods. But would firefighters be willing to subject themselves to the new technology? (Seth, T., Chaudhary, V., Buyea, C., & Bone, L. 2011) What technologies would need to be developed to make a fully immersive virtual reality experience a reality? Would a fully immersive training environment be considered a successful multimedia platform as outlined in this paper and defined by the Motivational (Malone, T. & Lepper 1987) and Cognitive Theories (Alessi, S. M., & Trollip, S. R. 2001)?

# Literature Review:

## Virtual Reality

### Defining Virtual Reality

Van Wyk, & de Villiers (2009) define virtual reality as a rapidly growing technology which utilises the ever-increasing power of computers to simulate real-world and imaginary environments and situations with a high degree of realism and interactiveness. Ahn, Bailenson, & Park (2014) define immersive virtual environments as those that allow individuals to see, hear, and feel digital stimuli as if they were in the physical world. Ahn, Bailenson, & Park's (2014) definition of an immersive virtual environment is considered a partial immersion as only three of the five senses are involved. Visual, tactile, and auditory feedback are the three stimuli current developers commonly react with in virtual reality environments. Augmented Reality super imposes a graphic, video or audio onto a real time environment that show every perspective and adjust to every movement of the user. Augmented Reality can be used for marketing or in heads-up-display devices for military or emergency service applications (Smart, 2011). Augmented Reality does not provide immersion, instead it affords valuable data in an easily accessible form.

Hülsmann, F., Fröhlich, J., Mattar, N., & Wachsmuth, I. (2014) stated that one possibility to make virtual worlds more immersive is to address as many human senses as possible. They presented a system for creating wind and warmth simulations in virtual reality environments utilizing fans and infrared lamps. Although the tools used were rudimentary they proved that learners felt more present with the addition of these stimuli. In 2009, scientists from the Universities of York and Warwick displayed a project called 'Towards Real Virtuality' at the Engineering and Physical Sciences Research Council showcase in London, in which all five senses of a learner were stimulated by encasing learners in a Virtual Cocoon. This was the first

time a full immersion environment had been created which included on-demand smells and tastes that were pumped into users' noses and mouths. The technology is in its infancy and pumping on-demand recipes is most likely the wrong way to go about a full immersion experience, as your smells are limited to the ingredients on hand (The first virtual reality technology to let you see, hear, smell, taste and touch, 2009). As impractical as cocooning learners may be, a virtual experience that engulfs all senses is a step in the right direction for development of virtual reality as a whole.

## Advances in Graphics

Visual feedback is currently one of the most important stimuli a virtual reality environment can provide. Advances in processing power has given designers powerful graphic capabilities that provide ultra-realistic environments. Video games provide a great backdrop into what developers of virtual reality environments are able to create. In 1989, the Commodore 128 desktop computer system afforded games with simple shaped graphics and high pitched pings from the sound card. One of the most popular turn-based simulation games of 1989 was SimCity. SimCity used black and white basic outlined shapes and text to sculpt buildings, roads, railways, and waterways to build a turn-based simulation where you were mayor of a virtual town, seemingly challenged with the task of building it into a money making metropolis.

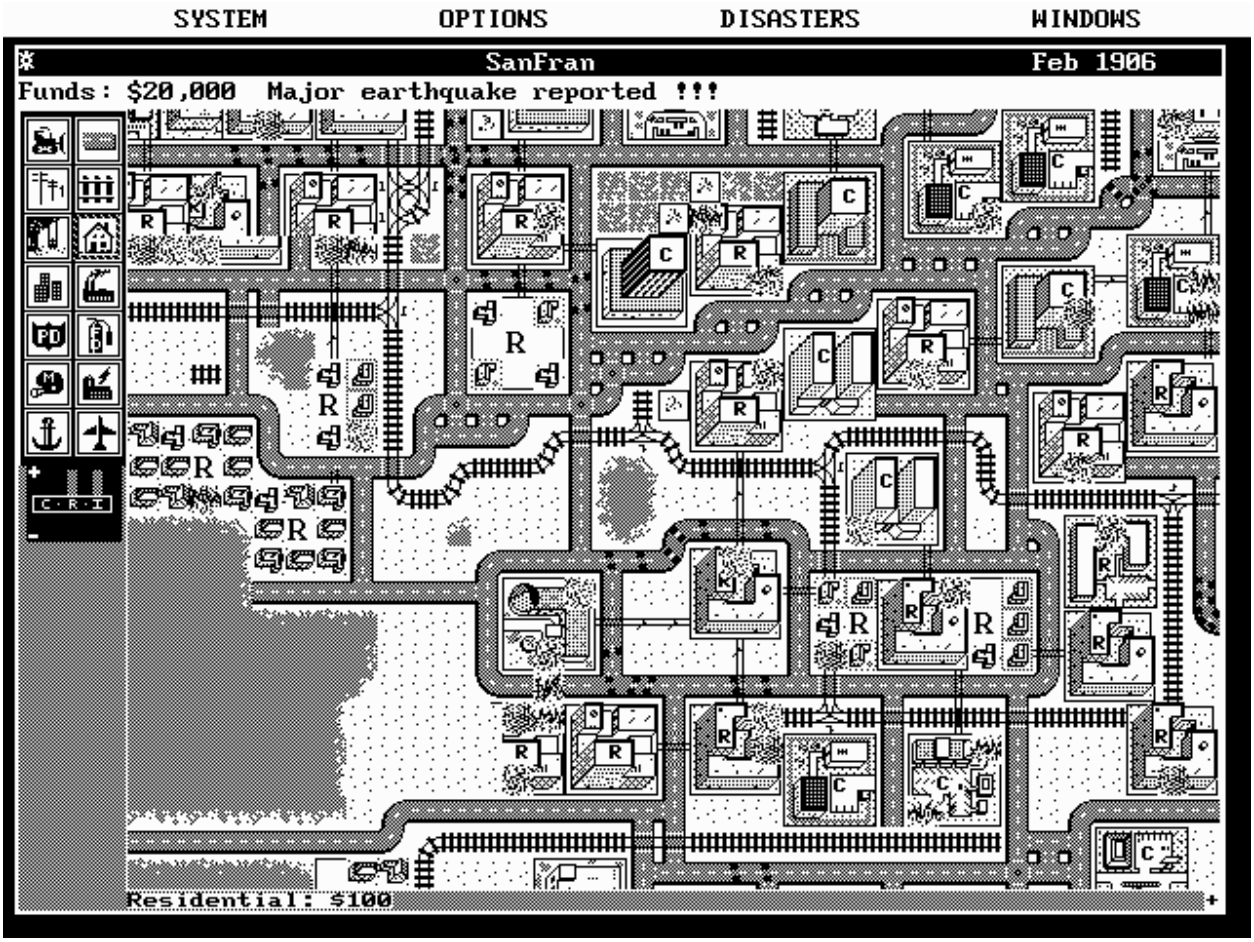


**Figure 1:** Sim City as seen in 1989. (http://gestion.vieux.jeux.free.fr/data/simcity.png)

Although graphics were considered archaic by today's terms, content reigned king.

The level of realism in video games continually increased and in 1994 it prompted the creation of the Entertainment Software Rating Board (ESRB), The ESRB was on a mission to suggest age appropriateness based on content within video games across all platforms. 1994 saw the first 32 bit gaming system with the release of the Sega 32x and a first-person firefighter game called *Farenheit*. *Farenheit* used full-motion video and timed pop-up menus that displayed consequence driven directional decision making. It was plagued with slow load times and the only consequence driven decisions were reflective of directional in-game movement. No skills or tools could be utilized but it did provide a realistic walk through that a firefighter may encounter

at an incident.

**Figure 2:** Screenshot from Fahrenheit with decision timer. (https://www.youtube.com/watch?v=p7R04h3Hsjw)

Four years later in 1998's *Jurassic Park: Trespasser*, graphics were clunky, unshapely and had very poor animation characteristics but immersion had increased as the user had constant control of the movement within the game. Elements were interactive such as doors swinging with accompanying hinge sounds, however latency was a major issue. Although Electronic Arts, one of the largest game manufactures in the world missed the mark with fluidity and graphics of *Jurassic Park: Trespasser*, they were on the right track for creating three dimensional interactive environments and would continue to push the envelope and eventually pave the way to the beautiful gaming environments built today.

Recent (2014) environments created for the Playstation 4 video game console has proven that racing games appear more lifelike with screeching/smoking tires and the sounds of metal being crushed, while violent video games involve blood splatter, bullet wounds and the utterly

horrifying sounds of war in realistic surround sound. Advances in viewing technology with high-definition LED televisions that are relatively inexpensive providing a large sized display makes the realistic gaming experience available to a wide consumer base.

**Figure 3:** Forza Motorsport 4 for Playstation 4. (http://www.clickonline.com/)

With graphics that are shown high-definition at high frame rates, large crystal clear LED displays, and sound that surrounds users and fills the room, it's inevitable that partial immersion would enhance the lifelike experiences and full immersion would afford an entirely unforeseen sense of realism in a virtual environment. Currently the gaming experience is limited with high definition visual feedback, controllers that provide minimal tactile feedback, and sound that provides auditory feedback.

**Virtual Reality in Education**

## Semi-Immersive Training

"Computer-generated simulation environments can be utilised to provide 3D representations of real, recreated, abstract, or imaginary environments that may otherwise be of impractical size, infeasible distance, prohibitive cost, or too significant a hazard to experience in person" (Baylis, 2000; Dalgarno & Lee, 2010). The firefighter command training virtual environment developed in 2003 by St. Julien, T. U., & Shaw, C. D, although only eleven years old, seems visually archaic. Using 3D Studio Max St. Julien & Shaw developed an environment with character animations that included: cutting, chopping, walking, crawling, climbing, pulling and spraying a hose, and carrying a variety of tools. Current "Computer-generated 3D environments based on gaming technologies are able to simulate real world environments by providing users fluid control within a realistic 3D space."

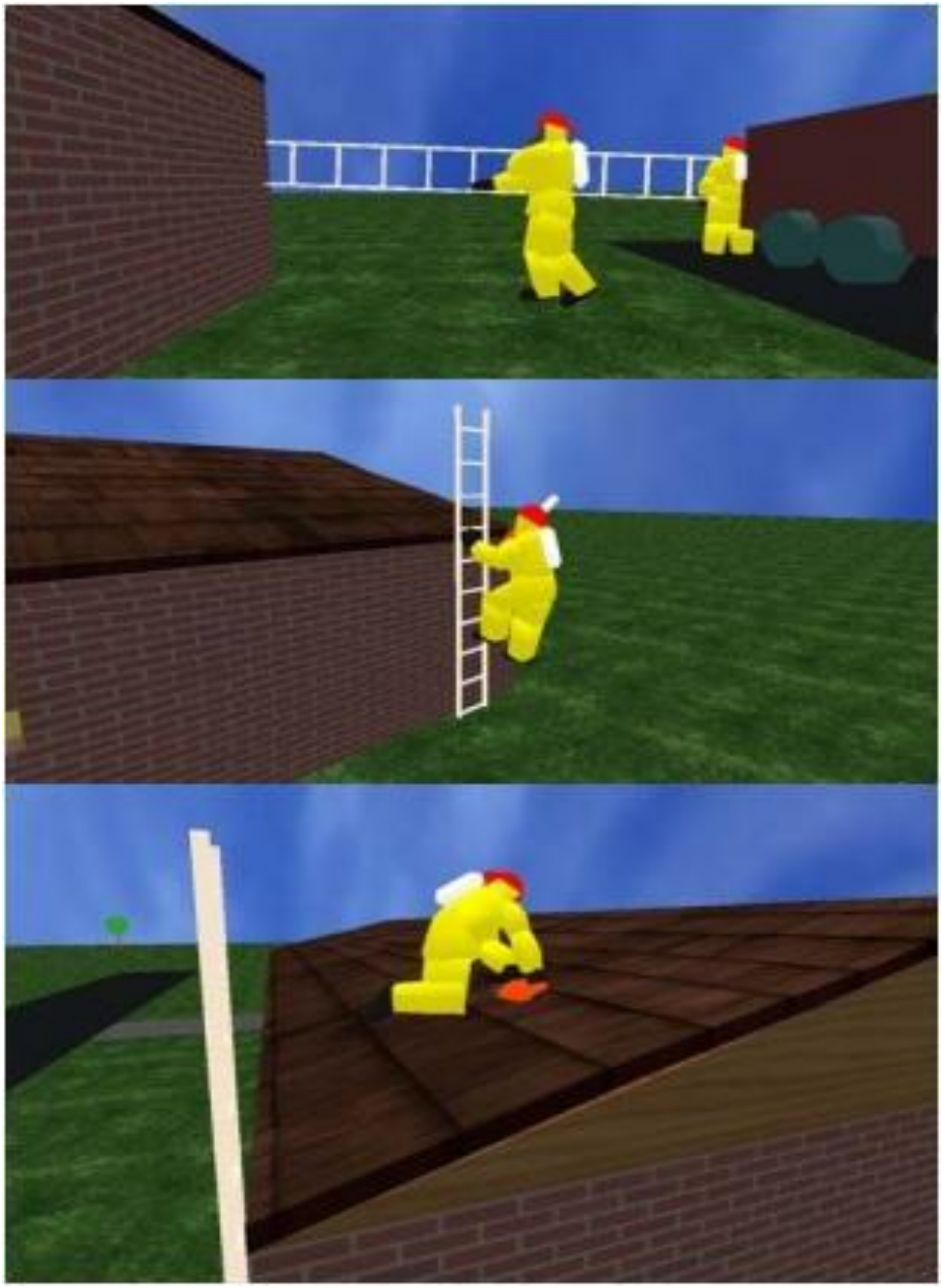

**Figure 4:** St. Julien, T. U., & Shaw, C. D, 2003 Training Environment

In the span of seven years, the amount of progress in the visually advanced graphic capabilities of each of the environments is astounding. One virtual reality environment proposed by Lee, J.,

Cha, M., Choi, B., & Kim, T. in South Korea in 2010 used a pair of flat panel monitors with three dimensional graphics along with a joystick and heat lamp that provided haptic feedback. One screen would provide a virtual reality experience while the other would provide an augmented reality view to see what other firefighters in the command are experiencing. Although not a fully immersive virtual reality experience it was a major improvement over previously developed firefighting training environments.

**Figure 5:** Lee, J., Cha, M., Choi, B., & Kim, T. 2010 Training Environment

The 2015 commercial introduction of the head-mounted virtual reality display called Oculus Rift will bring semi-immersive virtual reality to the gaming and training community. Currently developers are working on creating content and Oculus is working on increasing the resolution, decreasing the weight of the head mounted display and generally improving the user experience by reducing latency. “There are hundreds of virtual reality experiences being created, more content in the last year made for virtual reality then in the last 20 years combined” (Luckey 2014). There are currently a variety of experiences available for download to the Oculus Rift

developer kit including racing, space exploration, a roller coaster experience, a virtual reality movie and more.

Stehling & Schäfer (2014) created 3D models of different orthodontic problems by creating high resolution scans of teeth into a computer. These 3D models were created to make parents aware of the variety of orthodontic problems as well as possible solutions. The 3D models would also be used to create a learning environment for students of orthodontia. Instead of using an Oculus Rift the images would be presented in a learning management system using Moodle. Utilizing Moodle the learning management system could be viewed in many commonly used internet browsers but would fail to afford learners a true virtual reality experience. In creating the 3D scans and learning management system, Stehling & Schäfer studied the introduction of 3D models into Orthodontia laying the groundwork for future learning opportunities in 3D including Oculus Rift.

Rémi Rousseau conducted a project for the Moveo foundation with Dr Thomas Gregory, Professor of Surgery and Medicine, at the Paris Descartes University and surgeon at the European Hospital Georges Pompidou. They created an experience for use with the Oculus Rift by using two synchronized GoPro cameras placed on Dr Gregory's head while he was performing a total hip replacement (Rousseau 2014). Students studying hip surgeries could then use an Oculus Rift to view the video and get a first person view of what the surgeon was seeing during the operation. The video provided a unique opportunity for students as normally they would attend a surgery but not necessarily see what the surgeon was looking at, the Oculus Rift video would also afford rewind, pause, and fast forward options. The next logical step for virtual reality training with an Oculus Rift would include the use of real surgical tools that provide haptic feedback.

**Motivation Within Virtual Reality**

## Motivational Theory

Malone's Motivational Theory (1987) involving motivation as a principle for learning in multimedia included four relevant factors; challenge, curiosity, learner control, and fantasy. A fully immersive virtual reality environment would be a perfect candidate for a multimedia learning platform that could fulfill all four factors in Malone's theory.

**Challenge:** Malone, T. & Lepper (1987) stated that challenge was the greatest single factor in creating a successful multimedia learning platform. The multimedia would have to prove challenging by creating tough but attainable goals from the onset and the difficulty of the challenge should be adjustable to the learners performance level.

The proposed fully immersive virtual reality firefighter training platform could provide a multitude of challenging environments based on skill level, job the learner is training for, as well as ongoing variables within the simulation based on in-training performance. Challenge difficulty can range from simple tasks such as procedural fire hose training all the way up to a five alarm multi-family residential scenario where the learner is training to be an incident commander. In progress variables such as changes in conditions, structural stability, and flammability of a structure, can alter the difficulty of the environments based on the learners experience or performance.

**Curiosity:** Malone, T. & Lepper (1987) separates curiosity into sensory curiosity and cognitive curiosity. Sensory curiosity is explained as items that attract a learners senses, such as visual or auditory elements with a learning environment. The proposed fully immersive virtual reality firefighter training platform could provide elements across all senses; visual, tactile, auditory,

olfactory and gustatory. The sound of a child screaming out for help, a backdraft that blows out a window, the smell of burning chemicals, are all elements within the proposed environment that could trigger sensory curiosity.

Cognitive curiosity is defined as an element that conflicts with what a learner has already experienced or learned previously. A fully immersive experience could provide specific details to a situational challenge that may be overlooked in traditional memorization by book or video or changed from what they experienced during training in ideal conditions. It could also allow for alternative experiences that may provide additional knowledge for learners by allowing them to train in a rare scenario such as a fire in a commercial warehouse, or an over-crowded residence.

**Learner Control:** Learners will have complete control over the environment in the proposed training environment. Their actions will ultimately help to complete the specific task within the environment or will cause a partial or complete failure of the task. Given the example of a single house fire, a learner can succeed by safely entering the residence, rescuing a trapped child or pet and continuing to fight the fire from the interior. In that same house fire scenario the learner could utilize different methods of search and rescue including a flashlight, a thermal-scanner or simple auditory calls to survivors, all of which are used in real life search and rescue operations. This level of control will help keep learners motivated to continue and retain information from the learning environment.

**Fantasy:** Alessi, S. M., & Trollip, S. R. (2001) refer to fantasy as a situation that encourages learners to imagine themselves in imaginary contexts or events using vivid realistic images. Based on evidence of historical advances in computing graphics, the level of realism that would be presented in the proposed fully immersive virtual reality firefighter training platform would

be life-like. The time it would take to develop a means of integrating learners with a fully immersive experience would allow for further advances in processing power as well as advances in graphics, latency, and rendering.

## Cognitive Theory

A fully immersive simulation used as a learning environment would utilize some of the major methodologies for a successful interactive multimedia using cognitive theory learning principles defined by Alessi, S. M., & Trollip, S. R. (2001).

**Perception & Attention:** The current state of graphic computing power will undoubtedly provide a superior experience for learners. Life-like orientation objects and cues will be used to increase the ability of the participants in the learning environment to navigate and orient themselves in the virtual world (Bayyari, A., & Tudoreanu, M. E. 2006). "Environmental richness could provide situational context, which refers to the surroundings in which knowledge and meaning making are present" (Chwen Jen Chen1, c., & Chee Siong, T. 2013). Realism of not only objects but movements will help retain users attention.

**Encoding of Information:** Being a highly visual presentation of information with interactive auditory elements the fully immersive environment will provide learning deemed the *multimedia effect* (Alessi, S. M., & Trollip, S. R. 2001). The *multimedia effect* is a theory that "suggests that learning is enhanced when complementary information codes are received simultaneously." In a fully immersive virtual reality environment there are multiple modes of information being received including visual, tactile, auditory, olfactory and gustatory feedback.

**Memory:** The key to remembering perceived and encoded information is organization and repetition. A simulation is easily repeatable and the consequence based decision making will demand users repeat the simulation until a correct path is chosen. “Accurate recognition memory can be supported by a specific recollection of a mental image or prior experience (remembering), reliance on a general sense of knowing with little or no recollection of the source of this sense (knowing), or guesses” (Mania, K., Badariah, S., Coxon, M., & Watten, P. 2010). Information within the simulation will be organized into a realistic representation of real-life buildings and situational experiences.

**Active Learning:** With a fully immersive virtual reality simulation there is no need for a keyboard or joystick. The learner will physically feel themselves walking, crawling, and carrying the weight of their compressed air tank. The only interaction that will take place is a brain to computer communication, however it will take place constantly and unknowing to the learner as the environment encompasses every sense of the learner in a virtual manner. If a learner fails to act quick enough the virtual heat will become overwhelming, the virtual smoke will enter their lungs as the compressed air runs out and the pain of being injured on the job or the joy of saving a life will feel as real as if it were happening in real life.

**Locus of Control:** An immersive simulation is the near definition of locus of control. The learner not only has complete control of the learning environment, they are completely engulfed in the environment as all of their senses are connected to every action taken within the simulation. “When individuals feel that their individual behaviors directly influence the wellbeing of the environment, they are more likely to be concerned about and actively care for the environment” (Ahn, S. J. (Grace), Bailenson, J. N., & Park, D. 2014). Calling for help over

the radio and using perceived information to decide a course of action are instances in which the learner has control. A fully immersive firefighter training environment would afford learners complete control of their virtual actions and environments, requiring complete mental focus, hence providing a unique informational experience.

**Transfer of Learning:** With a life-like environment built on structures found locally the simulation would afford learners with unparalleled experiences. Structures that are created as digital replicas including common stick-built construction, used locally for many single and multi-family homes, would prove valuable when compared to current cement block burn towers used in training. Training in a very realistic environment close to what a firefighter will face when showing up to an incident, the transfer of learning would be considered near transfer. (Alessi, S. M., & Trollip, S. R. 2001).

**Safety and Costs Associated with Virtual Reality**

For firefighters in Westchester, New York, a life-like virtual reality environment that requires life threatening decision making during training, could save lives when dangerous situations are encountered on the job. Current training methods used at the Fire Training Center at 4 Dana Road in Valhalla, NY don't properly represent on-the-job experiences. Unlike most houses, the training building is fireproof, which means trainees don't have to worry about structural issues or burning materials impacting air quality (St. Julien, T. U., & Shaw, C. D. 2003). The Fire Training Center is also expensive to operate, therefore when a drill is being practiced, large groups are necessary to justify the cost. In a real-life situation the group that shows up for an incident will be significantly smaller, hence the training is inaccurate. A fully immersive virtual reality environment would allow trainees to access a wide variety of training

scenarios that are difficult to reproduce in the real world, including training in smaller groups or structures relevant to firefighters in Westchester, NY. For some types of training; immersive virtual reality environments can offer lower costs and reduced danger (Sowndararajan, A., Wang, R., & Bowman, D. A. 2008). With some software development the virtual reality environments could afford learners a superior training experience by providing simulations of actual buildings representative of the area including crowded multi-family homes, hospitals, and office buildings. "The users are not just passive observers in the computer-generated world, but are interacting with the various components of the environment in real-time" (Arns, L., Brisbin, M., Foldes, D., & Holland, J. D. 2006). If users are interacting through an immersive simulation with digital environments that are exact replicas of local buildings and structures, life-like consequence driven training situations without inflicting actual harm, could prove invaluable as a learning tool.

## Method:

### Technology Needs

A fully immersive environment will require development of technologies to connect the central nervous system and computers. Two possible methods of brain to computer interactions are externally through nodes placed on the skin, or internally through nanotechnology.

Lotte (2011) discussed using electroencephalography to control 3D virtual reality environments. Results were limited to movements of left and right by learners thinking of moving their left or right hands and the electroencephalography determining which way to move the figure in the three-dimensional environment. There were many issues including, the

application of nodes to the scalp, calibration, and latency problems. Limitations of external nodes cited by Lotte, could potentially be solved by implanting sensors in the brain.

Brain computer interactions utilizing nanotechnology are not currently used but could be developed in the near future. Google X is working on nanoparticles, less than one-thousandth the width of a red blood cell, which would seek out and attach themselves to cells, proteins or other molecules inside the body. The technology is estimated to be five years away and would primarily focus on searching for cancer and other diseases. Skeptics suggest that Google is likely more than five years off, and will face huge challenges, both technically and socially (Barr & Winslow 2014). A similar technology could eventually be used to navigate nanoparticles to the brain to allow signals to flow quickly from a learner's brain to a computer and back again. Noted futurist, inventor, and Google employee, Ray Kurzweil stated that nanobots will enter the brain and interact with our biological neurons and be able to shut down our real eyes and real skin and enable us to experience virtual senses in virtual bodies exploring fantastically real virtual environments (Big Think 2011).

**Prototype Development**

Creating a realistic environment that will reflect all of the interactions a learner would have with the proposed fully immersive virtual reality simulation is not possible as the technology is yet to exist. This prototype (http://youtu.be/Tyyxff__zbY) serves as a demonstration of what a fully immersive experience may look like and help convey different aspects of the technology to learners who could potentially become future users. This prototype was about creating an experience that can emulate some of the interactions, and create consequence driven decision-making that reflects a few decisions that would have to be made in a fully immersive environment. Decision-making would be a constant challenge in a fully

immersive experience whereas the project developed created a go or no-go decision making process at the end of each video chapter. Similar to the traditional choose-you-own-adventure books once popular among teenagers, a choice at the end of each chapter would decide the content of the next. The experience uses first-person footage of an over-crowded suburban house fire similar to one that would be encountered in Westchester County, New York. The footage (http://youtu.be/f0H6slvAGfc) was captured by a high-definition Contour Helmet camera on the helmet of a Rescue Company Officer who was responding to a call of multiple people trapped in a house fire in Alameda County, California.

The footage was captured from YouTube using clipconverter.cc and edited in Adobe Premiere to smaller clips. Cuts were made at strategic locations in the captured footage to allow for consequence driven decisions to be made by the learner when published on YouTube. The clips had colored graphics that were created in Adobe Illustrator and added in Adobe Premiere to represent the learners body temperature, heart rate, and compressed oxygen tank level as reflected by the situational conditions. These graphics are representational of just a few items a learner would feel if the prototype was a fully immersive experience. The learner could choose one of two options at the end of each video highlighted as YouTube annotations, which would link to a subsequent YouTube video. The next video would either allow the learner to continue on the mission or display a mission failure message and allow the learner to continue on with the correct decision.

During the creation of the prototype, certain design choices were made that would impact learner control and experience. One design choice created a ten second still frame where the annotations would appear and allow the learner to make a decision as where to proceed next. After implementation and testing it was realized that ten seconds was not enough time for the

learner to read the annotations, process the text, make a decision, and move the mouse over to the chosen annotation and click their decision. Transitioning the still frame from color to grayscale and changing the music, created an environment in which the learner realizes it is time to make a decision. Increasing the decision making time to fifteen seconds allowed the learner


**Figure 6:** Screenshot of Annotations on Grayscale Still at 1:05 of Prototype Video 1

enough time to read, process and make a decision, without removing the difficulty that comes along with making a consequence driven decision in a timed setting. Although timing, color, and music, choices were critical in the design of this prototype, a fully immersive environment would nullify this entire portion of the design process.

In the proposed fully immersive experience the consequences of decisions made by the learner would feel immense in comparison to the prototype developed. Decisions would be made constantly on-the-fly and there would be no need for breaks in the environment for learners to decide their fate. The instant feedback of feeling immense heat from a backdraft, running low on

compressed air, or miscalculating a life-saving decision could generate situations that would source an immense amount of stress and experience for learners.

## Implementation:

Feedback from active firefighters would prove critical in determining the future impact of immersive virtual reality simulations used for training purposes in Westchester, New York. On November 18, 2014, I met with a group of 11 active firefighters from Independent Company in Valhalla, New York to share the idea of a fully immersive virtual reality training environment and survey them for feedback. I shared my Contour Helmet video simulation series of a first-person view of a suburban house fire. The prototype is similar to the first-person view captured by Rémi Rousseau created with Thomas Gregory while operating on a patient's hip by representing what a fully immersive virtual reality training environment could look and sound like. With advances in technology the simulated house fire training prototype I created could become a fully immersive experience providing tactile, olfactory and gustatory feedback. After viewing the simulation they were handed a questionnaire that contains both open and closed questions. Subjects were asked not to identify themselves, upon completion the respondents were to seal them in an envelope before handing them in.

## Prototype Conclusions:

The survey was met with mixed reactions from respondents as they felt it could benefit learners where current training methods have failed, but that it could never fully replace current training methods.

**Realism**

The brave firefighters all agreed that no matter how realistic the fully immersive virtual reality training situation is, it could never be traumatic enough to cause a learner post-traumatic stress. In fact, they unanimously agreed that the realism of an immersive environment could benefit learners by affording training in unique situations, such as fires in warehouses, overcrowded residences, or scenes with frantic bystanders, none of which are simulated in current training methods. One participant described training in the Firefighter Training Facility as “Ideal Situations” therefore denying learners an authentic experience that a fully immersive virtual training program could provide.

**Training**

A few respondents stated that the current promotional testing is mere memorization of a book and that a fully immersive reality environment could benefit those seeking leadership positions. While 9 of 11 of respondents concluded they would voluntarily train in a fully immersive virtual reality environment only 3 of 11 respondents think that it could replace traditional firefighter training methods. One respondent suggested that you would still need traditional firefighter training methods as virtual training might prepare a trainee mentally but it fails to prepare a trainee physically. There were multiple responses that suggest current training methods either prepare them for situations that are unlikely to occur in the local area or failed to provide realistic training for situations that do occur. 11 of 11 of respondents agree that a fully immersive virtual reality environment could better prepare learners for realistic localized situations one would encounter on the job including but not limited to; being first on a scene with limited manpower, unique vehicle accidents with injuries, and hazardous material spills. Being properly trained for incidents that occur regularly, firefighters could potentially reduce the risk of

property damage and more importantly human injury and/or death. One respondent suggested that a fully immersive training environment could also provide mitigation training at an incident as part of a promotional test for those seeking to climb the ranks within the firehouse.

**Conclusion**

A total of 11 respondents gave a total of 56 written responses, 20 of which were concerns about the level of realism used in current training methods. These 20 answers provided feedback that confirmed a well-developed set of virtual reality environments could provide a more realistic training incident. Respondents are concerned about the accuracy of the currently provided training and seem partially open to the idea of a supplemental fully immersive virtual reality training program. However this should only be considered preliminary finding focused on a small sample size (n=11) who only viewed a prototype.

Could the life-like experience within a fully immersive virtual reality training experience provide a superior learning environment for a consequence-driven training program? Yes, a virtual reality program could afford multiple training scenarios at a lower overall cost providing superior mental training, however physical training would still be necessary for strength and agility. Once hardware is developed and the software is created, a fully immersive virtual reality environment will determine if it could offer safe and viable alternatives to traditional firefighter training methods. But would firefighters be willing to subject themselves to the new technology? (Seth, T., Chaudhary, V., Buyea, C., & Bone, L. 2011) According to data collected from the focus group, participants are more likely to willingly participate if the virtual environments provide knowledge and experiences that could reduce physical and property damage while on the job. What technologies would need to be developed to make a fully immersive virtual reality experience a reality? The main obstacle in achieving a fully immersive experience is the

development of human-brain communication hardware and software. According to Moore's Law the processing power to provide such an experience will be available. Would a fully immersive training environment be considered a successful multimedia platform as outlined in this paper and defined by the Motivational (Malone, T. & Lepper 1987) and Cognitive Theories (Alessi, S. M., & Trollip, S. R. 2001)? Yes, a fully immersive training environment would successfully meet criteria for a multimedia platform as defined by the Motivational and Cognitive Theories.

## Research Conclusions:

Finding palpable results for a learning environment that is yet to exist is not possible, however we can look to the past and the progression through today to determine possible outcomes for tomorrow. Creating fully customizable, life-like training scenarios that engulf learners in an environment that they will encounter on the job should increase retention of knowledge. According to Sowndararajan, A., Wang, R., & Bowman, D. A. (2008) a key result is that increased immersion had no effect when the procedural learning task was simple. However when it comes to a more complex procedure, increased immersion had a significantly positive effect on performance, particularly for the error metric. This suggests that with complex and high-intensity training, such as that of a firefighter, a more immersive learning experience would be needed in order to learn a procedure effectively. A full immersion could provide a superior training environment for any job or task as simple as proper fire hose procedures or as complex as an incident commander in a large structure fire. Advances in brain-computer interactions and the continued advancement of processing and graphic technologies can only improve the immersion experience for learners. Figure 7 below visualizes learning with different levels of

immersion in conjunction with the complexity of a particular task according to the key result Sowndararajan, A., Wang, R., & Bowman, D. A. (2008) found.

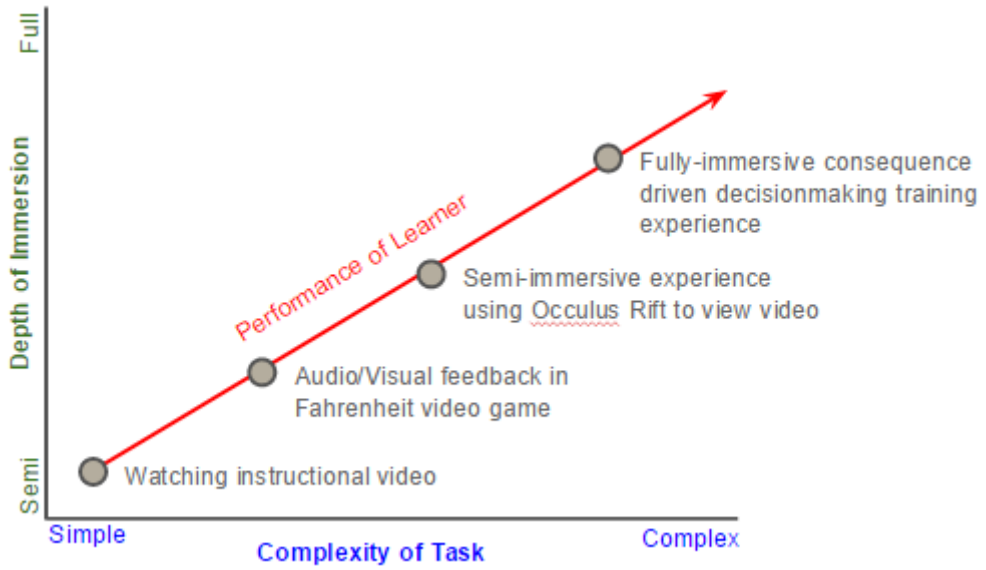


**Figure 7:** Learner Performance based on Depth of Immersion and Complexity of Task

Focus group research has shown that firefighters in Westchester, NY believe a fully immersive experience could provide useful and realistic training for incidents that are overlooked or infeasible within the current training regimen. Although the immersive experience may provide a positive training environment, the only incentive would be the ability of a trainee to increase their performance while completing duties within the current training regimen. Personal safety, intrigue, and the potential for knowledge gained are all personal motivating factors to partake in an immersive environment as part of regimented training.

## Future Research:

Future research should be conducted as technologies continue to advance at an exponential rate (Big Think 2011). The next firefighter virtual reality training environment that is

developed should be filmed with high-heat stereoscopic cameras attached to the helmet of a firefighter as they encounter various incidents. GoPro even sells a mount that allows for the use of two GoPro cameras for the purpose of creating 3D video. GoPro cameras in similar mounts have been shown to work at very high heat and therefore could be an affordable option for capturing firefighter footage. This footage could be edited for use in a head-mounted display such as Oculus Rift and could provide visual and auditory feedback for learners. Further immersion into firefighter virtual reality training environments will be dependent on the advancement of brain computer interaction technologies.

Taking the data into consideration, a review should be conducted of the entire current training procedure, including relativity of material covered, realism reflected in the exercises, and considerations for promotional testing. This study would prove useful not only for Independent Company in Valhalla, but county wide, as it could provide long-term cost savings for the Fire Training Center and Westchester County. Considerations should be taken to include a semi-immersive virtual reality experience as part of the initial training for firefighters at the Fire Training Center in Valhalla, NY.

Consideration should be taken for a future study comparing the skills of firefighters trained utilizing an immersive environment to those in a control group that only received traditional training techniques.

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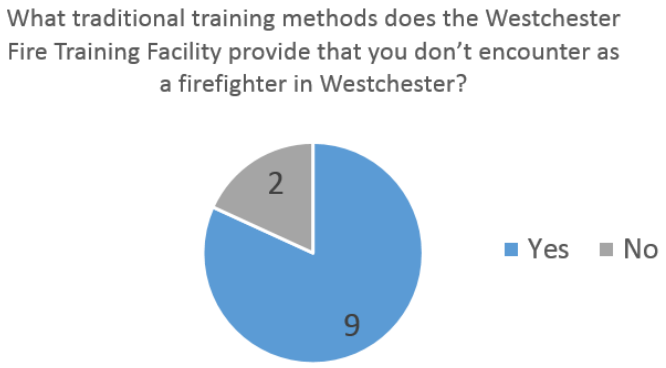
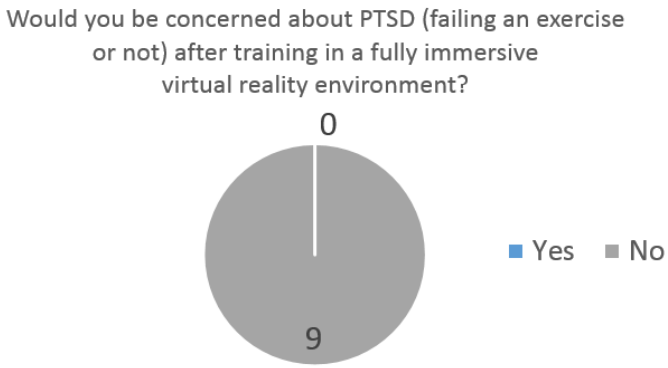
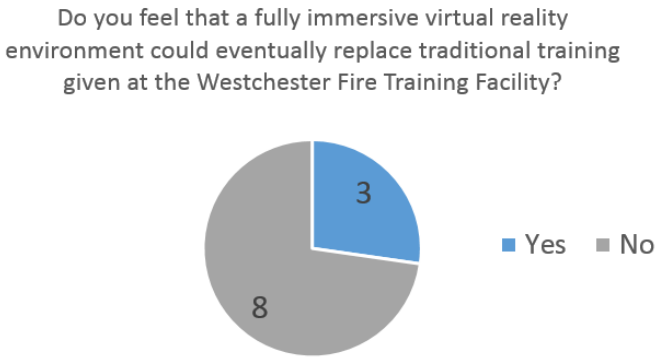
# Appendix 1:

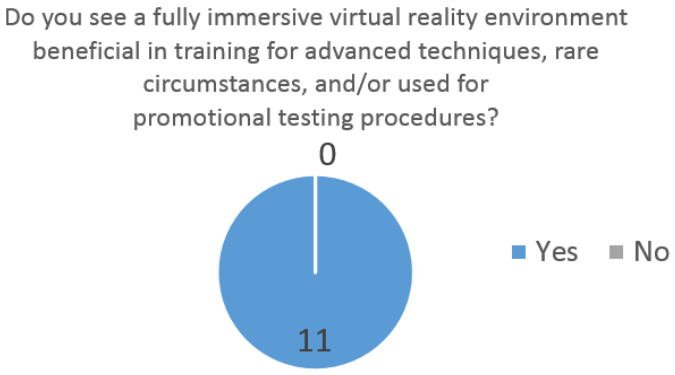
## Data collected from Focus Group







**What traditional training methods does the Westchester Fire Training Facility provide that you don't encounter as a firefighter in Westchester?**

- Train with a full crew when in reality there is a limited number of manpower at actual scenes until mutual aid shows up
- You are always in controlled environments and have plenty of help. Where here you have no idea who is showing or how many.
- High rise building fires, propane fires
- Very little, the academy goes over emergency situations and protocols, but what happens in training rarely happens in a real world scenario because situations at the training facility are "ideal situations"
- We have live training we have more guys instead of during the day when you and three guys show up to an incident
- They teach us about forest fires, but those are extremely rare in our area

**What challenges does traditional training at the Westchester Fire Training Facility leave absent that you could encounter as a firefighter in Westchester?**

- Westchester does have live fire training but it is a controlled environment. Reality of a fire is really not felt there.
- Nothing, they cover every aspect of training
- As a firefighter you never know who is showing up.
- Controlled fires at the training center, limited manpower at actual incidents, hazardous material response, commercial buildings/hallways - limited visibility, not know what is in the building
- May have limited crew at alarm
- We could have lack of manpower which is never an issue at the training facility and victims reactions and how to deal with them aren't gone over at the training facility
- Overpopulated homes

**Explain why you voluntarily train in a fully immersive virtual reality environment?**

- To better firefighter training if this will make training more realistic
- The opportunity to experience closer to life situations. When doing practical exercises, conditions are usually idealized, a VR program would enable experiences closer to real life.
- Progress
- Gives you visual when you just arrive at the scene
- Willing to try and any task learned can help
- I would because a virtual scenario could simulate many things that wouldn't be safe to do during a live burn at the training academy
- Depends on your age (worried about health complications)
- All new firefighting training is important
- It is a great way to see how your body and mind will react to a real life situation, not just having the thought of what would go wrong.

*Explain why you think it could provide a superior training experience?*

- If this makes you feel like you are in an actual scene it can condition the firefighter to expect the unexpected
- To experience what is going on in a real life situation. Actions that can't be experienced; ie. structure collapses, backdraft, etc. Because of the real dangers could be experienced interactively, because the physicality [bodily harm] isn't present.
- To experience a real situation without being in real danger
- Visual, heat and initial response procedures
- But could not replace physical training
- A virtual experience would be a superior form of training because the scenarios could change. It's less expensive and you could do things you couldn't do in real life training
- It would help fireman at the scene
- It will give you the full life experience

**What other benefits do you see to this training method over the traditional training given at the Westchester Fire Training Facility?**

- You can have different scenarios, for example a trapped firefighter or a missing victim. Hazmat situations or worse case scenarios.
- The running of the program with the trainee in different positions (command rescue, hose handling, use of various equipment) without having to mount an extensive program.
- You can create stressful environments that you would not see in real life.
- The training control burn tower is always the same layout, where here you can customize to any building, residential or commercial.
- Response procedures, size up
- Could be used anytime regardless of conditions such as weather
- At the facility during live fires, victims can't be live humans they have to be dummies. You could also simulate frantic bystanders.
- You would see things that you would not learn at a required training facility
- Able to run more training sessions, not many opportunities to practice extricating cars when they don't have enough cars or buses to use.

**Explain why you feel that a fully immersive virtual reality environment could eventually replace traditional training given at the Westchester Fire Training Facility?**

- Firefighters still need to have an actual hands on training as well. Still need to know how to stretch hose, tie, do an actual search
- Less need for equipment that needs replacement
- Virtual reality would be a great tool but you would still need real life environment
- All volunteer
- Need physical activity
- There's unlimited scenarios that could be generated while there is only 3 buildings to burn in at the training facility
- You still need training at the training facility
- You need the basic hands on training
- You will see that it is a much safer environment and will eventually become more practical

**Explain why you see a fully immersive virtual reality environment beneficial in training for advanced techniques, rare circumstances, and/or used for promotional testing procedures?**

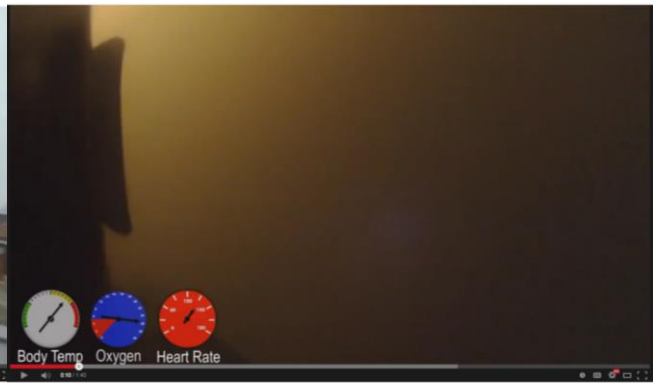
- The test questions for today's promotional exams are straight out of a book that pencil pushers wrote. If you can do actual scenes where a firefighter can mitigate a problem it would be great.
- Change to try out new and different things.
- There are stressful environments that you can train for but you will never see. By doing the virtual reality [training] you can try and train for these situations.
- We do not have options with training in large buildings; warehouses, hospitals, or offices.
- It could simulate multiple incidents and variable that can't be produced in a training scenario
- It would help the paid departments
- Pre-planning, hospitals, schools, commercial buildings
- You will be able to have simulated hazmat calls that you can't practice except for reading a training book.

## Appendix 2:

**Screen captures from Prototype** (https://www.youtube.com/watch?v=Tyyxff__zbY)

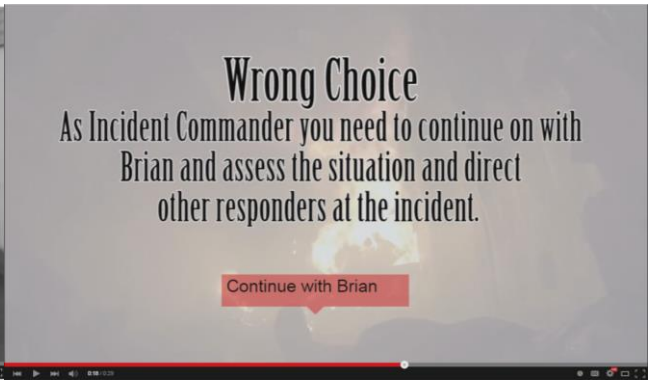
Also available by searching YouTube.com for ‘ed tatton video 1’


Introduction Screen 0:03 of Video 1



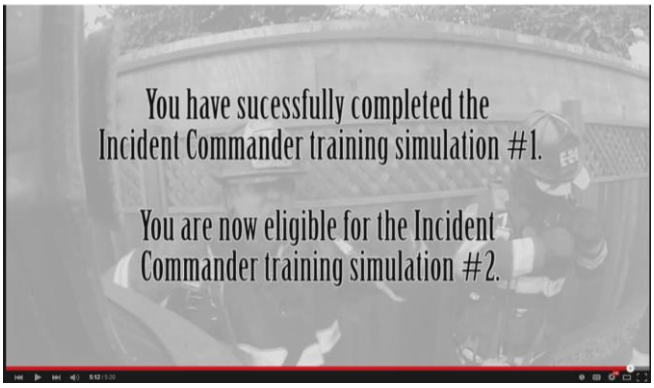

Smoke filled house searching for survivors 0:10 of Video 3


First set of annotations 1:05 of Video 1




First failure message with annotation 0:18 of Wrong Choice 1


Second set of annotations 1:03 of Video 2




Success screen at end of prototype 5:12 of Video 7