

AWARD NUMBER: W81XWH-12-2-0004

TITLE: Agile Development of Advanced Prototypes

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REPORT DATE: November 2014

TYPE OF REPORT: Final

PREPARED FOR: U.S. Army Medical Research and Materiel Command  
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for Public Release;  
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# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

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<b>1. REPORT DATE</b> November 2014		<b>2. REPORT TYPE</b> Final		<b>3. DATES COVERED</b> 15 Nov 2011 - 15 Aug 2014	
<b>4. TITLE AND SUBTITLE</b>  Agile Development of Advanced Prototypes				<b>5a. CONTRACT NUMBER</b>	
				<b>5b. GRANT NUMBER</b> W81XWH-12-2-0004	
				<b>5c. PROGRAM ELEMENT NUMBER</b>	
<b>6. AUTHOR(S)</b>  Scott Stevens  E-Mail: sms@cs.cmu.edu				<b>5d. PROJECT NUMBER</b>	
				<b>5e. TASK NUMBER</b>	
				<b>5f. WORK UNIT NUMBER</b>	
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b>  Carnegie Mellon University Office of Sponsored Projects 5000 Forbes Ave. Pittsburgh, PA 15213				<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>	
<b>9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b>  U.S. Army Medical Research and Materiel Command Fort Detrick, Maryland 21702-5012				<b>10. SPONSOR/MONITOR'S ACRONYM(S)</b>	
				<b>11. SPONSOR/MONITOR'S REPORT NUMBER(S)</b>	
<b>12. DISTRIBUTION / AVAILABILITY STATEMENT</b>  Approved for Public Release; Distribution Unlimited					
<b>13. SUPPLEMENTARY NOTES</b>					
<b>14. ABSTRACT</b> The goal of the work was to rapidly deliver a suite of high interest, high risk, advanced education and training prototypes at low cost. One of the unique features of this work is the incorporation of well-tested educational game and traditional video game design principles in producing engaging, educational and training experiences. During the project's period of performance, the ETC created seven functional prototypes: three interactive demonstrations allowing users to experience, from a patient's perspective life with three different prostheses: retinal implants, cochlear implants, and neuroprosthetics (EEG controlled artificial limbs); an interactive, virtual experience depicting the effects of the bombing of Hiroshima with geographical, medical, and historical accuracy; an exercise game designed that young adults find fun and willingly use; a simulation of a Personnel Decontamination Station for training in triage decisions for chemical casualties on the battlefield; and immersive experience showing genetic engineering's implication for the future of medicine.					
<b>15. SUBJECT TERMS</b> Agile Development, Games for Exercise, Games for Learning, Games for Training, Interdisciplinary Team Management, Scrum Methodology					
<b>16. SECURITY CLASSIFICATION OF:</b>			<b>17. LIMITATION OF ABSTRACT</b>  Unclassified	<b>18. NUMBER OF PAGES</b>  19	<b>19a. NAME OF RESPONSIBLE PERSON</b> USAMRMC
<b>a. REPORT</b>  Unclassified	<b>b. ABSTRACT</b>  Unclassified	<b>c. THIS PAGE</b>  Unclassified			<b>19b. TELEPHONE NUMBER</b> (include area code)

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**Contract: W81XWH-12-2-0004**

**Title: Agile Development of Advanced Prototypes**

**Final Report**

**Recipients: Tony Story**

**PI: Scott Stevens**

## **1. Introduction:**

The goal of the work was to rapidly deliver a suite of high interest, high risk, advanced education and training prototypes at low cost. One of the unique features of this work is the incorporation of well-tested educational game and traditional video game design principles in producing engaging, educational and training experiences.

## **2. Keywords:**

Agile Development, Games for Exercise, Games for Learning, Games for Training, Interdisciplinary Team Management, Scrum Methodology,

## **3. Overall Project Summary:**

During the project period, the ETC created seven prototypes: three interactive demonstrations allowing users to experience, from a patient's perspective life with three different prostheses: retinal implants, cochlear implants, and neuroprosthetics (EEG controlled artificial limbs); an interactive, virtual experience depicting the effects of the bombing of Hiroshima with geographical, medical, and historical accuracy; an exercise game designed that young adults find fun and willingly use; a simulation of a Personnel Decontamination Station for training in triage decisions for chemical casualties on the battlefield; and an immersive experience showing a thought-provoking perspective on genetic engineering's implication for the future of medicine.

### *Experiencing Living with Prostheses (Xense)*

During this period, three experiences were researched and developed. The applications are interactive demonstrations of retinal implants, cochlear implants, and neuroprosthetics (an EEG controlled artificial leg). The goal was not only a demonstration of the technology, but of the challenges and benefits that user's experience. Specifically, these experiences are:

A sound experience that emphasizes the progression of cochlear implant technology. A user observes and listens to a virtual environment. They are able to transition their environment through history as well as the simulated fidelity of a contemporary cochlear implant.

A visual experience that emphasizes the challenges of living with a retinal implant. Users are immersed in activities such as arranging blocks or opening a lock with a key, while wearing a headset that simulates seeing through a cochlear implant. It is up to them to learn to “see” as well as compensate with other senses like touch.

A neuroprosthetic experience that emphasizes the strangeness of learning something familiar in a new way. Using an EEG users first learn to flex a simulated prosthetic leg, ultimately progressing to walking with it.

The experiences:

1. Convey the unusual feeling of having to learn a “new” sense.
2. Show a progression from lack of sense to current prosthetic, and finally to future technology, emphasizing the differences.
3. Draw the attention of users, impressing them with potential of medical technology

The Cochlear Implant Audio Experience may be accessed here:

[http://www.etc.cmu.edu/projects/tatrc/?page\\_id=371](http://www.etc.cmu.edu/projects/tatrc/?page_id=371)

The Retinal Implant Visual Experience may be viewed here:

[http://www.etc.cmu.edu/projects/tatrc/?page\\_id=373](http://www.etc.cmu.edu/projects/tatrc/?page_id=373)

More information on the Neuroprosthetic experience is available here:

[http://www.etc.cmu.edu/projects/tatrc/?page\\_id=369](http://www.etc.cmu.edu/projects/tatrc/?page_id=369)

### *Nuclear Event Casualties (Atomic Zone)*

On August 6th, 1945 at 8:15am, an atomic bomb detonated over Hiroshima. Inspired by survivor testimonials and actual photography of the bomb site, Atomic Zone was produced using the Unity game engine to give users an interactive documentary exploring the extent of the damage in the aftermath of this historical bombing. The goal for this experience was to introduce the novelty of a walk-around experience in order to see the scope of the damage across different blast zone distances from the hypocenter. Research provided useful information on medical effects with respect to where victims were at the blast time, which lend themselves well to data grids of text or data visualizations laid out against top-down maps of the city. The experience provides a sampling of medical effects mixed in an immersive exploration of the space, to potentially deliver a more powerful experience with the following goals:

1. Create a historically and geographically accurate post-nuclear-bombing, Hiroshima based narrative driven experience;

2. Educate the public of the effects brought on by the use of nuclear weapons;
3. Demonstrate the different kinds of destruction based on the distance from the hypocenter;
4. Create the groundwork for medical training on the effects caused by a nuclear weapon.

The user takes on the role of an impartial observer in a documentary framework, with a linear exploration of the city after the bombing. The user is led through various waypoints on a journey into the hypocenter. The provided interactions are story discoveries, where the user can see additional animations from the past (between blast time and the experience's observer walkthrough), witness historical footage from before and after, read more from survivor testimonials, and access a medical overlay screen with patient specific information on injuries.

Atomic Zone may be accessed here: <http://test.idvl.org/AtomicZone/landing-2014.html>

#### *Exercise Game to Increase Cardio Activity. (CardioActive)*

According to the latest Pentagon figures, more than one-third of the roughly 31 million Americans aged 17 to 24 are unqualified for military service because of physical and medical issues, mostly due to obesity. CardioActive researched a way to make exercise something 17-24-year-olds will want to do using an active video game (AVG).

The team did research and experimentation into existing AVG trends and determined what it wanted to contribute to the genre that was both new and innovative. Demonstrations were created to discover how certain body movements worked with hardware, what types of body movements tended to raise the heart rate most, and what was fun and healthy about certain activities. Also researched were past studies about what motivates people to exercise. The findings can be viewed on the [Research and Design page](#) of our website.

The project developed a game called Webz of War for the 17-24 male and female demographic. It is cooperative in nature, and uses the Wii Balance Board, the Kinect, and a heart rate monitor to drive parts of gameplay. Participants navigate through a subway system infected with robot spiders while riding hover boards (Wii Balance Boards) and increasing the damage they can inflict on the spiders based on their heart rate.

Videos describing the project and game can be found here:  
[http://www.etc.cmu.edu/projects/cardioactive/?page\\_id=332](http://www.etc.cmu.edu/projects/cardioactive/?page_id=332)

#### *A PDS (Personnel Decontamination Station) Training Simulator. (Gas3X)*

This game simplifies and simulates the field training exercise conducted by USAMRICD (US Army Medical Research and Materiel Command) Chemical Casualty Care Division to teach soldiers about the flow of patients in the PDS through treatment and triage.

The PDS offers urgent Medical care and triage to chemical casualties in the battlefield. Players need to decide how the patients are treated at the station by assigning them a treatment method and a priority.

They do this by assigning casualties one of three treatment methods based on their health and diagnosis. Players also need to improve the station's facilities by efficiently utilizing manpower and resources. This will result in the expansion of treatment stations which enable more patients to be treated simultaneously.

The aim of the game is to educate chemical medics who cannot attend the actual field training course by providing them a simulation that can be accessed from a website. By doing so, medics will get a better idea of how the PDS works which will help save lives on the battlefield.

Videos describing the project and game can be found here:

<http://www.etc.cmu.edu/projects/gasx3/?cat=11>

The simulation can be played here: <http://www.etc.cmu.edu/projects/gasx3/Game/game.html>

### *Genetic Engineering's Implications for Future Medicine (TransNeuroSia)*

Project's goal was to create a physical, immersive experience that shows a thought-provoking perspective on the future of medicine.

The project explored a future where current cutting edge technologies like genetic engineering, organ printing and tech-implants are commonplace, and how they affect daily life. The final product goal was to provoke users to think about these advances in technologies, and how they can be used for the benefit of humanity.

Research in the field of genetic engineering has been increasing steadily throughout the years in spite of controversies and there have been a number of positive breakthroughs like gene therapy to treat hereditary diseases. While exploring genetic engineering the project came across research on genetically modified babies. A case where researchers supplemented women's defective mitochondria with healthy mitochondria from a donor was studied. The cells of the children born as a result of this research contained genetic information from both the women as well the father.

The final design explored areas of research in genetic engineering such as multiple parents for the same child, splicing human genes with that of animals and implants to improve lifestyles. The final product is called ProgenyX and is set in a future where genetic engineering is widely available and commercialized. ProgenyX has an interface which lets the users design their own baby by giving them the freedom to choose their child's genes and display the consequences of some of these choices.

Videos about the project and experience can be viewed here:

[http://www.etc.cmu.edu/projects/transneurosia/?page\\_id=25](http://www.etc.cmu.edu/projects/transneurosia/?page_id=25)

## **4. Key Research Accomplishments:**

"Nothing to Report"

## **5. Conclusion:**

The project demonstrated the efficacy of scrum-based agile development to rapidly deliver a suite of high interest, high risk advance prototypes at low cost. During the period of performance, seven functional prototypes were developed. Informal testing suggests that the prototypes were engaging and educational, that encouraged users to perceive experimentation and learning as entertainment.

## **6. Publications:**

AtomicZone:

Sciannameo, N., Cano, R., Durkin, N., Hamel, E., Hsu, J., Lee, A., Stevens, S., Harger, B., and Christel, M. *Atomic Zone: An Immersive Interactive Web Documentary Built with the Unity3D Game Engine*. Proc. 2013 18th International Conference on Computer Games (CGAMES) (Louisville, KY, July-Aug. 2013), pp. 191-196.

CardioActive:

Navarro, P., Johns, M. L., Lu, T.-H., Martin, H., Poduval, V., Robinson, M., Roxby, A., and Christel, M. *Webz of War: A Cooperative Exergame Driven by the Heart*. Proc. 2013 International Games Innovation Conference (IGIC) (Vancouver, BC, Sept. 2013), pp. 187-190. DOI: 10.1109/IGIC.2013.6659125

## **7. Inventions, Patents and Licenses:**

“Nothing to Report”

## **8. Reportable Outcomes:**

“Nothing to Report”

## **9. Other Achievements:**

Over the course of the project, thirty graduate students worked on prototype development in partial fulfillment of their Masters of Entertainment Technology degree.

## **10. References:**

“Nothing to Report”

## **11. Appendix:**

### **Personnel support under this work:**

Faculty:

Mike Christel  
Drew Davidson  
Chris Klug  
Jesse Schell  
Scott Stevens

Staff/Special Faculty:

Matt Champer  
Bryan Maher  
Jon Underwood  
Shirley Yee

### **Publications:**

# Atomic Zone: An Immersive Interactive Web Documentary Built with the Unity3D Game Engine

Nicholas Sciannameo, Rodrigo Cano, Noreen Durkin, Eric Hamel, Jason Hsu, Anabelle Lee,  
Scott M. Stevens, Brenda Harger, Michael G. Christel  
Entertainment Technology Center  
Carnegie Mellon University  
Pittsburgh, PA USA

**Abstract**—*Atomic Zone* was developed at the Entertainment Technology Center to immerse a student in the after-effects of a nuclear bomb blast through a virtual 3D walkthrough. The tone strives to be apolitical, presenting Hiroshima soon after its 1945 bombing. The Unity game engine was used to present narrative aspects through visuals, sound, and animations, allowing students to witness the damage that a nuclear explosion can inflict. The experience features historical anecdotes and medical treatments for survivors of the blast, with a self-paced navigation prompted by elements placed in the rendered 3D environment. A stylized look was chosen for rendering scenes and characters, rather than photo-realism, with historic photos interspersed in the interactive documentary to reinforce accuracy and the mapping to real world episodes occurring within Hiroshima on that day. This paper notes the development and first testers' reactions to the work, with implications for other game designers dealing with significant morally charged world events.

**Keywords**—*interactive web documentary; immersive 3D historical experience; game development process; Unity game engine*

## I. INTRODUCTION

On August 6, 1945, the first atomic bomb was dropped on the Japanese city of Hiroshima. Japanese children are taught about the event and nuclear aftermath starting in elementary school at roughly ten years of age. They have access to visual materials, listening to survivors visiting the schools for continued learning, and relevant museum visits, e.g., the Hiroshima Peace Museum [1] and its online database [2]. For most American students, the date carries no meaning, as there is a gap in teaching about the influence of atomic bombs between American and Japanese schools. Further, even medical professionals are unfamiliar with diagnosing injuries that have resulted from such a blast. Producing an experience following the bombing in Hiroshima may serve to introduce American students to the event and aftermath, and could provide the foundation for medical training regarding nuclear exposure. The Entertainment Technology Center (ETC) developed *Atomic Zone* during a semester-long project. The interested reader can search out the newsletters and play the "game" for greater detail and insight behind the points made in this paper [3]. The Unity game engine was used to produce the 3D experience, as it was felt that a fully immersive 3D experience would satisfy one goal of motivating American high schoolers (and older) to interact with the presented scenes. Of course, the topic is much more serious and morally charged

than many game topics as it ties back to a significant historical event, and so the team considered their work as an "interactive experience" or "immersive, interactive documentary" rather than "game." This paper discusses design decisions for *Atomic Zone*, the iterative development process involving high school age and older (age 14 and up) playtesters, and some early formative work. It concludes with recommendations on how other game and interactive experience designers/developers can deal with very serious events in meaningful ways.

## II. ATOMIC ZONE: BEGINNINGS

On August 6th, 1945 at 8:15am, an atomic bomb detonated over Hiroshima. Inspired by survivor testimonials and actual photography of the bomb site, *Atomic Zone* was produced using the Unity game engine to give users an interactive documentary exploring the extent of the damage in the aftermath of this historical bombing.

Unity was chosen as a tool offering support for rapid prototyping of 3D navigable worlds, ones built with 3D modelers and 2D texture artists working together to create an immersive experience. The goal of the work, to have a walk-through encounter, moved the team beyond a series of web pages or a 2D rendering of the historic event. With 3D as a focus, the choice of the Unity game engine allows the 3D experience to be run with the Unity plug-in within the major web browsers. Unity offers other platform export options, but those were not pursued here.

The development team began by checking numerous video documentaries, discovering that many had a bias. The goal for *Atomic Zone* was to remain apolitical while introducing the novelty of a walk-around experience in order to see the scope of the damage across different blast zone distances from the hypocenter. Some sites offered quite useful documents on medical effects with respect to where victims were at the blast time [2], which lend themselves well to data grids of text or data visualizations laid out against top-down maps of the city. The team wished to provide a sampling of medical effects mixed in an immersive exploration of the space, to potentially deliver a more powerful experience with the following goals:

1. Create a historically and geographically accurate post-nuclear-bombing Hiroshima based narrative driven experience;
2. Educate the public of the effects brought on by the use of a nuclear weapon;

3. Demonstrate the different kinds of destruction based on the distance from the hypocenter;
4. Create the groundwork for medical training on the effects caused by a nuclear weapon.

The development team at first wanted to create a story narrative in which the user takes on the role of a parent entering Hiroshima after the bombing in search of a missing child. Early testing of the idea found it lacking in being able to remain apolitical: the player would become very emotionally invested in the search. The narrative changed so that the user takes on the role of an impartial observer in a documentary framework, with a linear exploration of the city after the bombing. The user is led through various waypoints on a journey into the hypocenter. The provided interactions are story discoveries, where the user can see additional animations from the past (between blast time and the experience's observer walkthrough), witness historical footage from before and after, and read more from survivor testimonials.

The early versions also lacked a narrative framework introducing the user to the experience and wrapping it up, especially needed to set proper context for a general public unfamiliar with the date or event. Present-day Hiroshima and its lantern commemoration of the event was used to tie the historical event to current times, while introducing an element of hope into the experience. The lantern was subsequently used as a visual marker in the graphical user interface for the walk-around experience, noting points where individuals' detailed stories and photos could be revealed. Fig. 1 shows an intro screen and wrap-up screen used to frame the virtual walkthrough experience.

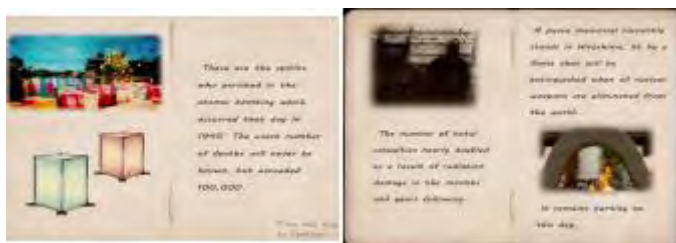


Fig. 1. Bookmarking the walking through Hiroshima, pages of a story animate to open story (left), and conclude story (right). The story opens: "Every year, on August 6, the citizens of Hiroshima float glowing paper lanterns down the Motoyasu River. These lights are meant to guide ancestral spirits back to heaven." It concludes with a picture and reference to the peace memorial currently standing in Hiroshima.

### III. DEVELOPMENT PROCESS: REVISING THE PRESENTATION

At first, the art style was semi-realistic, with bump-mapped smooth shading. After playtests and review by ETC faculty and experience design experts visiting the ETC, the style was revised to semi-stylized with simple bump mapping and cel-shading. The reaction of users to the rendered victims was still strong, a queasy feeling of discomfort that the characters were off-putting in some way. The development team ran into the uncanny valley for video games [4]: trying to push for photo-realism or even just more accurate rendering for human characters in the experience had a negative effect on users. As noted in [4], another approach to human character rendering in

games can be to use stylized art forms, and that was done with *Atomic Zone*. A more anime look with no shading and ink brush lines was used, the models were low-poly and angular in general, with few rounded edges or detailed areas. People were designed with highly exaggerated proportions: very lanky limbs, big heads and extremities, and few curves. Yet, the chosen rendering was still realistic enough to symbolize the varying injuries noted in the experience. The color palette for the entire experience is highly desaturated, using saturated colors only for areas of focus such as injuries. The evolution of wounded human character renderings in the experience based on user feedback is shown in Fig. 2.



Fig. 2. Evolution of human rendering, from too much emphasis on realism to an abstracted form (right) that tested much better with a general audience.

The built environment had to convey a sense of the destruction in Hiroshima, retain key historical buildings, yet be realizable for the team to construct in one semester. *Atomic Zone* contains 25 buildings, including the A-Dome, 4 non-playable character (NPC) models as illustrated in Fig. 2 right, 12 unique characters with medical overlays and textures showing varying injuries, and 6 rings of destruction. Wooden buildings were blasted down and burned by the blast; their rubble was used to constrict the user's navigation through the experience to a path through the 6 rings, as shown in Fig. 3.

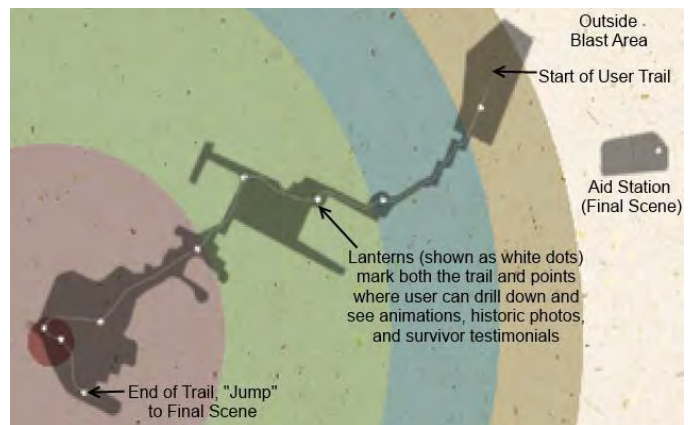


Fig. 3. Map of experience, with user walking through zones of thermal radiation, light air blast, ionizing radiation, heavy air blast, and the hypocenter, before walking through a smoke screen to be transported out to the aid station for the final scene. Player can range in the dark-gray shaded areas of the map (i.e., not forced to a strict linear walkthrough along one line).

Dickie argues that within contemporary games, fantasy has developed into complex narrative structures with opportunities for exploration, collaboration, and challenge [5]. The narrative environment fosters motivation and serves as the organizational framework for the interactive environment. Table I summarizes intrinsic motivation and the *Atomic Zone* design according to the framework posited by Dickie [5].

TABLE I. DESIGNING *ATOMIC ZONE* TO MOTIVATE ITS USERS/LEARNERS

<i>Intrinsic Motivation</i>	<i>Atomic Zone Design Elements</i>
Choice	When to walk or stop, where to walk (within shaded navigation areas in Fig. 3), which lanterns to explore deeper, which NPCs to examine for medical history and prognosis, when to exit
Control	Navigation path (within boundaries), where to gaze, how deeply to explore the experience
Collaboration	Not a factor for this experience: user is exploring alone
Challenge	Finding all lanterns, exploring all stories, capturing photos along the way, examining all encountered people where examination is offered as an option
Achievement	Progress through Hiroshima to hypocenter and then aid station in final scene, knowing more about post-nuclear bombing as a result of the journey and explorations along the way.

In light of the advice in Dickey [5], the player is not forced to sit through a number of animations and slide shows of photographs. Playing all of them would make *Atomic Zone* a more linear documentary with the same experience for all, and decrease the narrative setting of being "in" the city after the bombing and being able to explore on your own. Playtests with high school and college students confirmed the value of choice and control in the experience; the players decide which lanterns to interact with to see what they contain. The player's curiosity is triggered by elements in the rendered world, e.g., a tricycle lantern (Fig. 4). The player, rather than the game, decides whether a deeper exploration of historic photos (e.g., from [1] or [2] or [6]) and back story is played at lantern points, e.g., here a photo of a tricycle found amidst the wreckage.



Fig. 4. Partial screen shot of user seeing lantern on walkthrough by tricycle (left); player action of taking a picture of this lantern will show animation/testimonials/photos related to this location/theme with prior/next buttons (at right, with photo of a tricycle [1] found amidst the wreckage).

The player view point is first person, outside of entity. He or she moves around the virtual Hiroshima using standard keyboard movement controls, and also uses the keyboard to take pictures, see picture inventory, sequence through animations and historic photos, use a Geiger counter, and examine NPCs. To guide the user toward the hypocenter, both lanterns and factoid floating text sheets in the game GUI illustrate the way. Walking through a factoid will typically occur as the player progresses, and causes that fact to be displayed briefly on the screen, e.g., "Thermal radiation caused first, second, and third degree burns." The screen flow for the user is shown in Fig. 5.

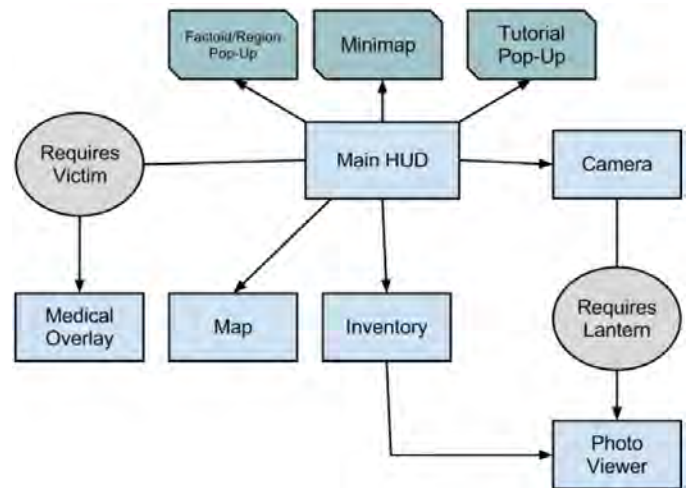


Fig. 5. Screen flow chart for *Atomic Zone*.

#### IV. ATOMIC ZONE: AN ILLUSTRATED WALK-THROUGH

The screen shots help the reader appreciate the transition through different blast zones, but note that there is audio accompaniment as well, with voiceover tracks, ambient music, sound effects, and theme music. Playtesters pointed out the value of the audio for setting mood. It develops as you travel toward the hypocenter, and moves from a quiet forested peaceful soundscape outside the blast zone toward a more disconcerting tone as you approach the hypocenter. The player starts well away from the blast, as shown in Fig. 6. The lanterns and white paper factoids light the way of the trail, with the mini-map in the upper right aiding navigation as well as educating the player on blast zone.



Fig. 6. Walking toward Hiroshima on Aug. 7, 1945, with a factoid visible in center to mark the journey toward hypocenter.

The player controls whether to take a picture at lantern points, like that shown in Fig. 7. If the picture is taken, then relevant material deepens the experience at that point. Here, there are bodies in the water, and the extra narrative revealed by taking a picture discusses the appeal of water to survivors of the blast, but also its danger as many drowned while trying to soothe their burns. The historic photographs are very powerful, and the extra animated flashback sequences tie what is seen in Fig. 7 to what occurred between the bombing time and this point, while also connecting the virtual walkthrough setting with the historic photographs.



Fig. 7. Light air blast zone: bodies seen in water.

As the player progresses the wooden rubble disappears, the soundtrack becomes more dramatic, the Geiger counter clicks if activated more steady, and the visuals more sparse. Fig. 8 shows a streetcar in the player view at left, and if the player takes a photo here, the photo viewer sequence includes the historic photo shown in Fig. 9. The message is reinforced that this Hiroshima is shown in a historically accurate manner, allowing for stylistic rendering to match the stylized people (i.e., simplified geometry, washed out coloring).



Fig. 8. Ionizing radiation zone: streetcar hulk, with lantern prompt icon.



Fig. 9. Photo from Nov. 14, 1945 showing damage to the streetcar system, taken 3000 feet northeast of the hypocenter.

The vignettes that play when taking a photo at a site can be quite powerful flashbacks. Shaders were used to heighten the visual drama, e.g., smoke, fire, and black rain in Fig. 10. Later, in the aid station, the catastrophic medical results of drinking the black rain will be apparent.



Fig. 10. Flashback animation triggered by player; such flashbacks accompanied by text, here stating "Within 40 minutes of the bombing, a black rain began to fall on Hiroshima. The water was highly radioactive, but victims, desperate for water, fell to their knees and drank."

The player experiences more rubble, but perhaps surprisingly some intact masonry structures in moving into the heavy air blast zone, with screen shot in Fig. 11.



Fig. 11. Walking in Heavy Air Blast Zone, A-Dome visible.

Within the hypocenter, the story of the A-Dome, its current use, the blasting of buildings white, and other anecdotes can be witnessed by the player taking of a photo at the lantern spot. The visuals change when the player takes a picture as shown in Fig. 12, with the traditional "camera" feedback of corner lining and center focus point. By leaving it up to the player, the journey from beyond the blast point to here can take from four to forty minutes. The length depends on how many pictures the players take along the way, how much they stray from the center path and explore, and how long they dwell on historic photographs like that shown in Fig. 9.



Fig. 12. The Hiroshima Prefectural Industrial Promotion Hall (A-Dome), the only structure left standing near the hypocenter.

After seeing the A-Dome, the trail leads through a smoke screen that transforms the player out to an aid station beyond the blast zone. In the aid station are numerous patients which the player can examine, as shown in Fig. 13. The art in the game remains stylized, but upon examination the details are presented with historic photographs. The medical overlay shown in Fig. 14 presents specific medical information and offers a more personal approach to injury than what was witnessed during the walk-through.



Fig. 13. Aid station, where player can navigate toward a patient and examine him or her, leading to the medical overlay display.

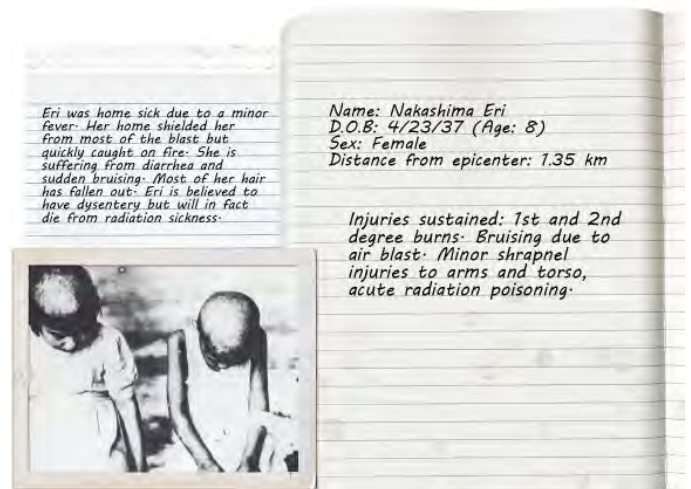


Fig. 14. Example of medical overlay screen with patient-specific details.

After working through the patients, the player can photograph the exit lantern from the aid station and trigger the ending sequence. One screen from the ending sequence, a concluding one with the Hiroshima Peace Memorial, is shown in part in Fig. 1 (right portion).

## V. CONCLUSIONS AND FUTURE WORK

*Atomic Zone* is not just about the facts, but also about an engaging, exploratory experience. The facts are available in other online resources [1, 2], while a walk-through experience offers additional motivation for a broad demographic [5]. *Atomic Zone* is about observation and walking around, experiencing the scale of the damage and getting a sampling of what injuries one would expect to see at varying distances from the hypocenter. Under user control, the user can see photographs of the aftermath as well as rendered flashbacks at selected "lantern" points on the journey, experiencing in greater detail what the event was like. Additionally, users can also assess the medical condition of people they come across.

Some general lessons learned include the difficulty of forcing a narrative: an impartial, unspecified observer walking through without a back story worked best. A general audience

of high schoolers through adults may not all know how to use WASD keys for in-game navigation, so an in-game tutorial is necessary to bring all players up to speed. Playtesting can also educate game designers and lead to better choices. For example, the designers initially thought that historic photographs would detract from the experience and should be minimized. Instead, they are viewed as essential by testers, a highlight of the experience, interesting on their own and for their confirmation of what is rendered in the scene (e.g., the tricycle of Fig. 4). Playtesting resulted in the number of photos used at lantern story points increasing dramatically. The pacing of the experience worked well, remaining under player control as the player decides when and where to walk on the general trail toward the hypocenter (Fig. 3). The player could self-regulate the timing of the most devastating and moving aspects of the post-nuclear experience.

Two possible areas for future work are to polish the experience more completely, and to test specific design elements. The current experience has some typos in text elements, some needed streamlining on GUI buttons (e.g., disabling them when not functional, such as the next button when no additional content is present), and improvements in some user communication (e.g., the exit lantern in aid station) which could be fixed with more development time.

An experiment could be set up whereby lantern stories automatically play as users pass by that neighborhood of the trail, rather than being triggered by user action, to run an experience with less choice and control by the user. Results from such a test could confirm conclusions drawn by Dickie [5] that players will invest more in and learn more from experiences if they retain choice and control. The value of the walk-through element of the experience could be studied by establishing a baseline experience with the same lantern content, but no walking between lantern points. Again, prior work suggests that the navigation promotes user interest in the topic at hand versus more static delivery [5, 7].

Other possible experiments might isolate certain aspects of the game to confirm more formally the value reported by playtesters, e.g., of the soundtrack or historic photographs. The

interested reader is welcome to see more background on the reported work and play *Atomic Zone* via links from the ETC [3].

#### ACKNOWLEDGMENT

Thomas "Brett" Talbot, MD guided the development of the reported experience with insightful comments regarding the fidelity of medical treatments. This research and development project was conducted by Carnegie Mellon University and is made possible by a cooperative agreement that was awarded and administered by the U.S. Army Medical Research & Materiel Command and the Telemedicine & Advanced Technology Research Center, at Fort Detrick, MD under Contract Number: W81XWH-12-2-0004. The views, opinions and/or findings contained in this publication are those of the authors and do not necessarily reflect the views of the Department of Defense and should not be construed as an official DoD/Army position, policy or decision unless so designated by other documentation. No official endorsement should be made.

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# Webz of War: A Cooperative Exergame Driven by the Heart

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**Abstract**—*Webz of War* is a cooperative two player exergame utilizing a Microsoft Kinect, two Nintendo Wii Balance Boards, two heart rate monitors, and a controller PC. The innovative composition of the game system is discussed, emphasizing the use of heart rate to control the attack power of players as they encounter robot spider villains in the subway tunnel system. Heart rate is also used to track players' cardio workout: *Webz of War* is designed to be a fun experience which also delivers an effective workout. The production of the game is discussed along with playtests informing the tuning of the game to deliver an engaging experience, one that also happens to provide exercise for the player.

**Keywords**—*games for health, exergames, game design, heart rate monitor, Kinect, Wii Balance.*

## I. INTRODUCTION

A comprehensive survey of research into active video games concluded that games with a narrative appeal and an interesting setting may help sustain player interest in using the game, irrespective of or perhaps even in spite of the active exercise component to the experience [1]. As one example, adding a digital boat game changed a tedious treadmill run into a captivating experience with increased social interactions [2]. A design tenet for the game discussed here, titled *Webz of War*, is that it should provide players with an entertaining experience first and foremost, one that just so happens to require exertion. Video games that promote exercise through entertainment, without calling attention to the exercise components, may be more attractive to people who are not highly motivated to exercise [3].

The survey [1] noted that game input devices today are often tuned to support very well the recognition of particular player movements: the Nintendo Wii Balance Board for lower body, and the Microsoft Kinect for full body. However, active video games that require high lower body and/or upper body energy exposures are not necessarily those favored by players [1]: how do exertion and enjoyment correlate? *Webz of War* explores this question by following the iterative design and development of an experience involving upper and lower body motion meant for a broad demographic of both fit and unfit players. In agreement with [4] and [5], we refer to this game genre as "exergames": video games requiring physical exertion in order to play, with game challenges and opportunities to engage the player's participation.

Past studies in sports and physical exercise have suggested that exercising with others can have both social and health benefits [6]. Similarly, a survey of exergames shows that a multiplayer mode may contribute to sustained usage [1]. Exergames involving cooperative players have shown increased player engagement [2] and an ability to exercise in different locations while sharing an exergame experience [4]. Looking specifically at overweight and obese adolescents, cooperative play increased the intrinsic motivation of participants, increasing their energy expenditure [5]. From this foundation work, another design tenet for *Webz of War* is that it should support two cooperative players working through the experience together.

As for workouts, a broad sampling of exercise videos and short workouts to benefit the heart showed that the workout activity varied from low intensity to high intensity, that the heart rate was pushed to appropriate target heart rates with interspersed recovery periods. *Webz of War* is designed to make use of a heart monitor to determine if players are exerting themselves and experiencing these recovery windows. Heart rate monitors have been used as input in gaming, e.g., to create equitable experiences between people of different fitness levels [4, 7], or to dynamically adjust the difficulty level of an interactive simulation based on heart rate, skin response, and pupil diameter [8]. TripleBeat made use of heart rate monitoring in a mobile phone-based system to motivate runners to achieve predefined exercise goals [9]. The innovative use of heart rate monitoring in *Webz of War* is to increase the power of a co-located cooperative player in the game: an exercising player will have greater chances for game success. As with [8], a baseline heart rate is established for the player at the experience start, so that this technique rewards both fit and unfit players for their physical exertion. The remainder of this paper discusses the components of the game, its design and interface, and its reception by cooperating, exercising players.

## II. WEBZ OF WAR: GAME COMPONENTS

The game components for *Webz of War* were chosen to experiment with the exergames space, rather than be commercially viable, so a mixed bag of various devices was assembled based on the devices' established success. The team could have pursued custom sensors, e.g., the dome-type sensors made of textiles on socks and pants used in a dance game [10].

However, such custom sensors may require a great deal of effort to keep them working despite humidity, room temperature, body movement, and small player actions [10]. *Webz of War* focused on the playable experience first, rather than sensor tweaking and manipulation, by taking advantage of already proven and fielded game input devices. The Microsoft Kinect has very accurate skeletal tracking of one or two players as the game controllers. With two players, their upper body movements are recognized quite well when players do not overlap in physical space. However, navigating a 3D world by walking or running around a room naturally moves the player out of the Kinect recognition range and introduces tracking and occlusion issues. Navigating a virtual world through a Wii Balance Board has worked well for Wii Active exergames: the player's shifting weight can move the corresponding game avatar through the environment. The balance board appears like a hover board. Having the player stand on the balance board in the real world, while in the game scene the corresponding avatar stands on a rendered hover board, worked well with initial play tests conducted with tens of college students. After adding in the requested ability to have players choose male or female avatars, the stage was set for the game: Wii Balance Boards (two, separated enough from each other and from game to allow players freedom to punch in all directions) for virtual world navigation, Kinect for upper body tracking of both players, and a large display screen.

The game was built using the Unity3D game engine, integrating these input devices along with a heart rate monitor for each player with a Windows PC. A wireless Polar Heart Rate monitor worn against the player's rib cage transmits heart rate data to a nearby Polar Heart Rate receiver on an Arduino controller board, which is connected to the game computer through USB cables. A steady periodic reporting of the two players' heart rates is consumed by the game, first to establish a baseline heart rate for each, and then as data affecting the experience that the player has in the game. The video insets in the figures, starting with Fig. 1, show the two players interacting with the game, standing on the boards with gestures recognized by the Kinect. The Kinect is located under the large game screen about two meters in front of the players.

### III. WEBZ OF WAR: DESIGN DECISIONS

The driving innovation for the game is that the players' heart rates directly affect their in-game experience. As players' heart rates increase over their individual baselines, they become more powerful in the game. As a result, the players can see that putting more effort into the game gives them greater rewards, so they are more likely to stay engaged as they exercise. The narrative framework is that the players work together to travel through a series of underground subway tunnels and terminals, battling various-sized robot spiders, and collecting items, with the goal of reaching the end where the giant boss spider lives. The players must destroy the boss to win the game. The aural feedback in the game varies so that the players remain intrigued. High energy music often accompanies gym and exercise video workouts, and the hard rock soundtrack composed for this game apparently worked well. The fast-paced high energy score with distinct music for the tunnels and various stations was noted frequently by

playtesters as a strong point of the game. Sound effects for player actions, the spider pursuers, and various environmental noises appropriate for a subway setting are interspersed at appropriate points in the game to give additional aural texture.



Fig. 1. *Webz of War*, two players twisting side to side to free themselves from entanglement in web within subway tunnel. Video inset of two players at lower left shows activity (this video inset is not on game screen but used here for illustration). Animated "what to do" avatars at left and right bottom corners illustrate action to take, e.g., squatting, reaching, twisting, punching.

Fig. 1 shows the initial tunnel entryway. The baseline heart rate is being computed and the entrance begins passively, but then the players need to collect the green plasma ball ammunition while avoiding pursuing spiders and upcoming obstacles like the spider webs. In Fig. 1 the players are doing side to side twists to free themselves from an entangled web. Such twists, along with reaching up and squatting down to collect ammunition in tunnels, increase heart rate. Heart rate feedback and animated ammunition collection is shown via bottom corner displays for each player when the "what to do" help (as in Fig. 1) is not needed; see Fig. 2. The tunnel exercise is primarily lower body squatting and standing, plus additional reaching and twisting, with Kinect recognition driving the experience. The circles on the back of the color-coded hover boards are player health: here full green for 100%.



Fig. 2. *Webz of War* screen shot and corresponding player video inset: reaching and squatting on Wii Balance Boards in tunnel to evade pursuing spider, avoid webs, and collect ammunition. The Kinect is used exclusively here to track player posture.

After the tunnel, players are deposited into the first station. Players fight spiders together, able to chat with one another as they are in same physical space. Recharging health stations (red plus signs) and ammunition stations (green sparkling plasma blobs) are present in the environment, as well as various attacking spiders with different sizes, speed, abilities to launch webs, and health. Players launch green plasma shots at spiders by punching to aim the projectiles (aiming tracked

accurately by Kinect). The hover board's color-coding and animated feedback on score, health, and ammo count focuses attention for each player on their own board in the subway station (moved by shifting weight on Balance Boards). Players who actively cooperate are able to maximize success in these station encounters with clusters of spiders. Following success in a station, the players navigate via a chosen tunnel to the next station, providing alternating periods of intense activity and rest in agreement with the surveyed exercise workout patterns.



Fig. 3. *Webz of War* screen shot and corresponding player video inset: first subway station encounter. Players navigate space by shifting weight on Wii Balance Boards and defeat robotic spiders with punches (recognized by Kinect) that launch green plasma balls. The size and power of plasma balls is directly related to the player's heart rate: higher relative heart rate produces more powerful, larger plasma ball ammunition. A spider is exploding from a completed attack at top center.

#### IV. INFORMATIVE PLAYTESTING

Early playtesting confirmed a few points already in the plans of the game designer: to culminate with a boss fight, and to increase difficulty of stations as players advance through the tunnel system. New insights were collected, from at least four waves of tests conducted with 4-12 players each, mostly college students, including more feedback on: which hover board is mine; when I attack; when I am at risk; my own health score, ammo, and heart rate; effects of my actions (collecting, defeating, etc.). Perhaps the biggest feedback was the desire to have the game faster paced and more playful in a style reminiscent of old-style 2D arcade games with various attacking villains, comments given when the game was fully 3D camera-behind-avatar view as in Figs. 1 and 2. By animating the camera from this perspective to a top-down view upon entering a station (one shot in this transition shown in Fig. 4; top-down view is in Fig. 5), the players were rewarded with fast-paced 2D action with better awareness of overall spider location and pacing, while retaining the 3D nature of the overall experience. This transition worked well, as evidenced by player game data and surveys collected in subsequent play tests. The surveys also indicated an appreciation for the art style. Initially the stations were more sparse (like the tunnels), but after feedback, each station was given a unique flair with plants, fountains, and other decoration. Comic-book style colorful graffiti was added to the walls and this added visual texture was another aspect of the game receiving praise afterward from playtesters. At important points during the game, e.g., the introduction to the boss spider and its cluster of child spiders, the camera perspective briefly changes back to 3D for a peek inside tunnels and then back up to the top-down view of the station, as shown in Fig. 5. For playtesting with a

broad audience, the game's difficulty was modulated to easy, medium, or difficult, with the boss's invincibility, attack power of spider clusters, ammo and health recharge availability all adjusting to the chosen difficulty level. More difficult game settings required more player activity (twisting, punching, squatting, reaching) in order to succeed.



Fig. 4. *Webz of War* screen shot and corresponding player video inset: players at rest during transition from tunnel to station. The camera view is also in transition, from behind avatars to a top-down view as seen in Fig. 5.



Fig. 5. *Webz of War* screen shot and corresponding player video inset: concluding boss fight against supersized robotic spider and its assemblage of numerous compatriot spiders. The fountain in middle marks the final station.

Two important questions to test following the formative development of the game were whether players enjoyed the cooperative experience and whether they experienced any exertion as evidenced by tracked heart rate. At the university Spring Carnival, 58 new playtesters across fitness levels and genders, primarily college students, used the game for 5-7 minutes at a time. The testers were asked in a post-game survey whether they would play this game again, and with whom. As hoped for, a majority would play again with friends. Since playtesters could check more than one, percentages add up to more than 100%: 62% would play with friends; 55% with their younger siblings and/or children; 26% would play with boyfriend/girlfriend; 17% would play with parents. Video and survey evidence support the claim that the game is fun, with participants – eager to play again – ranging from young siblings to faculty in their 60s with varying fitness. The heart rate evidence showed a pattern of increased beats per minute, a drop during designed periods of transition (e.g., Fig. 4), and an increase as levels became more complex. Fig. 6 shows a representative heart rate from one of the Carnival players.

On the post-game survey, the respondents rated the game as "enjoyable" (average 3.95 on 5 point scale; see Table I) but as too easy in the "effort expended" rating (average 2.64). There

was no difference seen for gender, age, or fitness level. The overall easiness of effort is due in part to the players self-selecting what difficulty level to use, with a vast majority choosing an easy setting as they did not see the experience before. Players that rated the game highly also rated it as requiring more effort.

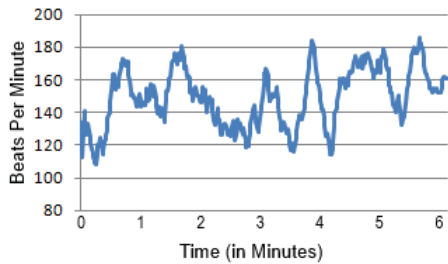


Fig. 6. Heart rate from a representative college student player during the game, showing periods of rest and work within the game and an increased heart rate into an appropriate range for exercise, as desired.

TABLE I. POST-GAME SURVEY DATA CLUSTERED BY QUALITY RATING, 58 PLAYTESTERS

Player Count	Quality <sup>a</sup>	Average Effort Rating <sup>a</sup>
1	1	3
3	2	1.67
13	3	2.38
22	4	2.41
19	5	3.21

<sup>a</sup>. Quality scale ranged from 1 (frustrating) to 5 (enjoyable); Effort scale from 1 (none) to 5 (a lot)

## V. CONCLUSIONS AND FUTURE WORK

*Webz of War* delivers on its objectives of being an enjoyable cooperative experience that modulates its players' heart rates as they move through the game. The recent review of exergames [1] suggests that adults found more energy expenditure less enjoyable, perhaps because the games were not designed first for fun. The trend of Table I, that players who believe they expend more effort are also rating the game as more satisfying, is worth more study, controlling for the game difficulty setting and incorporating actual heart rate data to augment the player survey rating on effort. Another obvious focus for the work is to test the use of the heart rate monitor in actually affecting the experience, versus a control set-up in which the monitor is still worn and reported in the game interface but does not change parameters like ammunition size and power. If players go through the game twice, controlling for ordering effects, will they rate the one that actually uses heart rate data to affect the experience more highly?

For *Webz of War*, the emphasis was to produce a fun exergame without concern for mixing hardware sources. As expected, the Wii Balance Boards worked great for navigation through the subway space, and the Microsoft Kinect excelled for two-player gesture recognition. The heart rate monitoring worked well as long as the Arduino receiver was physically close to the chest-strap wireless heart rate monitor, requiring an awkward set-up of controller boards on tripods near the balance boards. If the game were to be distributed commercially, the packaging of these components would need to be addressed. One could then possibly introduce a more sensitive heart rate

monitor not necessitating bare skin contact, which was an inhibitor to some playtesters.

The game continues to evolve based on the latest playtesting, e.g., the quality rating for the game from Spring Carnival may have been suppressed because of the lack of a playable tutorial to teach and give players practice in critical gestures like twisting, squatting, and navigating. Such a tutorial is being added into the game, along with other suggested improvements to better communicate effects of player actions. A challenge is how to best communicate that increased heart rate provides benefits in the game, as currently this effect is subtle. The expectation is that overall quality ratings will improve with subsequent playtests. *Webz of War* explores the space of cooperative exergaming offering dynamic heart rate monitoring for use as a game mechanic.

## ACKNOWLEDGMENT

Thomas "Brett" Talbot, MD guided the development of the reported game with insightful comments and useful references to a world of arcade games with the potential to inspire exercise. This research and development project was conducted by Carnegie Mellon University and is made possible by a cooperative agreement that was awarded and administered by the U.S. Army Medical Research & Materiel Command and the Telemedicine & Advanced Technology Research Center, at Fort Detrick, MD under Contract Number: W81XWH-12-2-0004. The views, opinions and/or findings contained in this publication are those of the authors and do not necessarily reflect the views of the Department of Defense and should not be construed as an official DoD/Army position, policy or decision unless so designated by other documentation. No official endorsement should be made.

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