Webz of War: A Cooperative Exergame Driven by the Heart

Paul Navarro, Megan L. Johns, Tzu-Hsun Lu, Heather Martin,
Vijay Poduval, Mat Robinson, Andrew Roxby, Michael G. Christel
Entertainment Technology Center
Carnegie Mellon University
Pittsburgh, USA
{pnavarro, mjohns, tzuhsunl, hmartin1, vpoduval, mrobins1, aroxby, christel}@andrew.cmu.edu

***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.

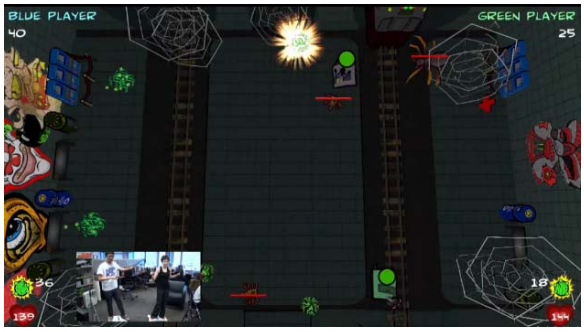

Fig. 3. *Webz of War* screen shot and corresponding player video inset: first subway station encounter. Players navigate space by shifting weight on Wii Balance Boards and defeat robotic spiders with punches (recognized by Kinect) that launch green plasma balls. The size and power of plasma balls is 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.

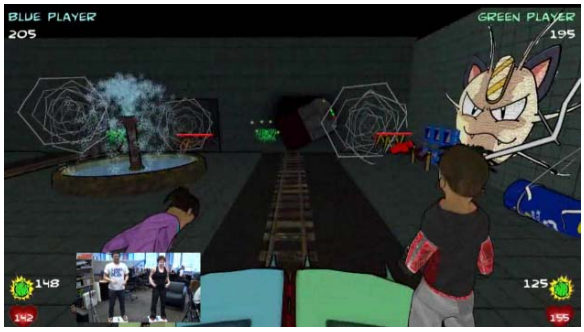

Fig. 4. *Webz of War* screen shot and corresponding player video inset: players at rest during transition from tunnel to station. The camera view is also in transition, from behind avatars to a top-down view as seen in Fig. 5.

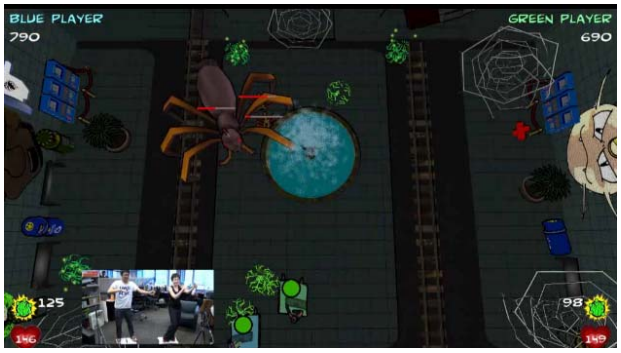

Fig. 5. *Webz of War* screen shot and corresponding player video inset: concluding boss fight against supersized robotic spider and its assemblage of numerous compatriot spiders. The fountain in middle marks the final station.

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.

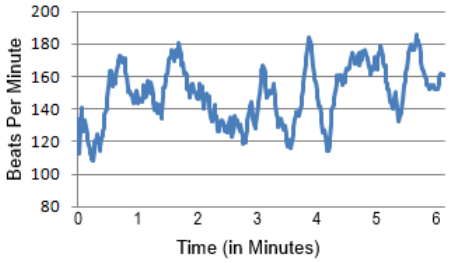

Fig. 6. Heart rate from a representative college student player during the game, showing periods of rest and work within the game and an increased heart rate into an appropriate range for exercise, as desired.

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

Player Count	*Quality*[a]	*Average Effort Rating*[a]
1	1	3
3	2	1.67
13	3	2.38
22	4	2.41
19	5	3.21

[a] Quality scale ranged from 1 (frustrating) to5 (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.

REFERENCES

[1] W. Peng, J. C. Crouse, and J.-H. Lin, "Using active video games for physical activity promotion: A systematic review of the current state of research," Health Edu. & Behavior, vol. 40, pp. 171–192, April 2013.

[2] M. Ahn, S. P. Choe, S. Kwon, B. Park, T. Park, S. Cho, J. Park, Y. Rhee, and J. Song, "Swan boat: pervasive social game to enhance treadmill running," Proc. ACM Multimedia, pp. 997-998, Oct. 2009.

[3] E. J. Lyons, D. F. Tate, S. E. Komoski, P. M. Carr, and D. S. Ward, "Novel approaches to obesity prevention: Effects of game enjoyment and game type on energy expenditure in active video games," J. Diabetes Sci Technol., vol. 6, no. 4, pp. 839-848, July 2012.

[4] F. Mueller, F. Vetere, M. R. Gibbs, D. Edge, S. Agamanolis, J. G. Sheridan, and J. Heer, "Balancing exertion experiences," Proc. ACM CHI, pp. 1853-1862, May 2012.

[5] A. E. Staiano, A. A. Abraham, and S. L. Calvert, "Motivating effects of cooperative exergame play for overweight and obese adolescents," J. Diabetes Sci Technol., vol. 6, no. 4, pp. 812-819, July 2012.

[6] R.S. Weinberg and D. Gould, Foundations of Sport and Exercise Psychology. Champaign, IL: Human Kinetics, 2006.

[7] T. Stach, T.C. Nicholas Graham, J. Yim, and R.E. Rhodes, "Heart rate control of exercise video games," Proc. Graphics Interface, pp. 125-132, May 2009.

[8] T. D. Parsons and J. Reinebold, "Neuroscience and simulation interface for adaptive assessment in serious games," IEEE Int'l Games Innovation Conference (IGIC), pp. 93-96, Nov. 2011.

[9] R. de Oliveira and N. Oliver, "TripleBeat: Enhancing exercise performance with persuasion," ACM MobileHCI, pp. 255-264, 2008.

[10] C.-M. Yang, J.-S. Hu, C.-W. Yang, C.-C. Wu, and N. Chu, "Dancing game by digital textile sensor, accelerometer and gyroscope," IEEE Int'l Games Innovation Conference (IGIC), pp. 121-123, Nov. 2011.