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Development of a Serious Gaming App for Individuals with Spinal Cord Injury

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Abstract

In this paper we describe the development of SCI Hard, a serious game designed to promote self-management skills among adolescents and young adults with spinal cord injury and dysfunction (SCI/D). With assistance and input from individuals with SCI/D and healthcare providers, SCI Hard was designed as a mobile gaming app that allowed for game play by individuals with high levels of tetraplegia. It takes approximately five hours to complete and consists of four levels that require the player's character to figure out how to get around with SCI, manage their health, and engage in activities so they can save the world. Evaluation of the game by fourteen individuals with SCI/D found that while reactions varied regarding the music and plot, in general, participants had a positive experience with the game and felt that playing it could benefit those with new SCI as well as a general audience. In conclusion, electronic games — if thoughtfully designed with input from the target population — appear to offer a potential avenue for engaging adolescents and young adults with SCI/D in the self-management process. The medium is familiar and allows a safe place to learn rules, test boundaries, and experiment with the connection between outcomes and actions/inactions.

Keywords

Spinal cord injury/dysfunction, adolescents, serious game, health management, intervention

Introduction

A serious game is "a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, public policy, and strategic communication objectives (Zyda 26)" (Charlier et al. 230). Serious games based on development of self-management skills have been created for asthma, diabetes, safe sex negotiation, and promoting nutrition and physical activities (Baranowski et al; Stinson et al; Thomas et al). They have been effective in improving self-care, increasing self-efficacy, reducing symptoms, minimizing secondary conditions, reducing emergency room visits, and decreasing health care costs (Lieberman).

Many of the individuals who sustain traumatic spinal cord injury (SCI) are from the millennial generation (adults born in 1981 to 1997; ages 18-37 in 2015; Fry). While the mean age for individuals with SCI is 42 years old (National Spinal Cord Injury Statistical Center; NSCISC), over half are in the 16 to 30 age range at the time of injury (SCI-Info-Pages). Younger patients with traumatic SCI are overwhelmingly male (NSCISC), many of whom need medical care for the first time in their lives. They have a high school education or less, with lower literacy levels and fewer resources; in addition, many come from ethnic and racial minority backgrounds (Burnett et al.). Millennials and younger generations, though, tend to have a high degree of technical sophistication (Dede; Litten and Lindsay), which can be leveraged to promote the transfer of knowledge and self-management skills. In particular, games that can be downloaded and played on a mobile platform such as a smartphone are likely to be accessed and played by adolescents and young adults. Importantly, data from a recent survey conducted by Meade and colleagues confirm similar patterns of use of this technology by individuals with SCI (Mayman and Meade; Mayman et al.).

Intervention Development

SCI Hard is a serious gaming application that was developed to tailor *Health Mechanics* (Meade), a self-management program created to facilitate management of spinal cord injury or dysfunction (SCI/D), into a format consistent with preferences and learning styles of the target population of adolescents and young adults. The *Health Mechanics* program is an evidence-based intervention that teaches or reviews the skills of attitude, self-monitoring, problem solving, communication, organization, and stress management.

Game development was shaped by current theories of health behavior and standard practices. In particular, we used the Model of Internet Interventions by Ritterband and colleagues (Ritterband et al.) to frame development; this model acknowledges a wide variety of mechanisms for changing behavior and leading to symptom improvement but articulates the importance of user characteristics and their influence on website (application/intervention) use as precursors that allow for behavior change. That is, an individual must access and use the Web, Internet, or game application in order for it to influence behavior change and the extent of use can influence the degree of behavior change, at least within certain limits. In particular, members of the millennial generation expect a high degree of interactivity, technological sophistication, and visual impact (Oblinger and Oblinger), and the degree to which these expectations are met will directly influence the individual's engagement, enjoyment, and ultimate use of the program. This model influenced design choices such that we attempted to prioritize characteristics that would be fun and engaging for the target population.

In addition, multiple theoretical and evidence-based approaches to learning and self-management were adopted throughout the development of SCI Hard to promote positive changes. These included modeling expectations for health behaviors, providing the opportunity

to develop skills through feedback mechanisms relating actions to consequences, reinforcing the impact of behavior and the importance of continued management practice (Meade and Cronin).

Multiple industry-proven tools and development platforms were used in creating SCI Hard to ensure a consistent and interactive experience. Art assets were modeled and animated in 3D Studio MAX (Autodesk, Vers. 2015, 2016), while the model's textures and colors were created in Adobe Photoshop (CS6) and Pixologic's ZBrush (Pixologic R4). Cut scenes for the game were assembled in Adobe After Effects (CS6), a common motion graphics tool, and then exported to the game using custom scripts so the game's logic could interpret artist-defined animations. The assembly of assets and introduction of game logic and mechanics relied on the Unity 3D game engine (Unity Technologies, Vers 3.5.6-Vers. 2017), which allowed for rapid iterations during development and cross-platform support. While the Unity3D platform provided many standard options for simulating lighting and materials, due to the unique visual style and "rolling horizon" effect found in the game, many custom tools and methods were developed.

Mobile platforms were targeted when developing SCI Hard in order to leverage their natural accessibility and mobility. The mobile device market represents hundreds of devices with many requiring special considerations for each combination of device and operating system (OS). Due to Apple's strict standards placed on iOS devices, initially only Apple iOS devices were supported to minimize potential variables that could impede the team's ability to respond to feedback from the advisory group. Additionally, a decision was made early on to support second-generation mobile devices to their present release due to minimum memory and computation requirements. Even with a limited number of potential devices and OS, it was discovered throughout the development process that undocumented limitations of the various devices introduced additional challenges. One such example was the precision with which a finger is

tracked across the surface of the screen. Many devices do not report a straight, equally spaced collection of contact points as one would expect if a consistent straight line was dragged with a finger. Thus, additional effort was required to smooth and anticipate inputs to ensure an effortless experience. During the beta release phase, support was added for the Android platform.

A primary concern with creating this game was to ensure that it was both engaging and accessible to individuals with SCI from the target population, including individuals with tetraplegia. An advisory panel consisting of healthcare providers and individuals with SCI from the target group was an essential part of the development process, as they provided feedback about game accessibility, content, dialogue, style, and pace. Based on this feedback, gameplay mechanics were crafted to ensure that the varying levels of physical and mental ability did not impede the gaming experience. The player uses simple finger or mouth-stick movements, focusing on a single action at any given time, such as moving through a scene, shooting, or interacting with a person or object.

In navigating through the game, players are required to monitor factors such as health, stress, and energy and are encouraged to optimize each of those factors through specific behaviors. In particular, health is a composite of managing skin integrity, bowels, and bladder as well as balancing diet and exercise. Players have to conduct pressure reliefs, organize and execute a catheterization ("cathing") schedule, and monitor bowel-related functioning throughout the game in order to stay healthy and be able to engage in other activities. Health and energy can be improved through visits and engagement with in-game healthcare professionals, including a physiatrist, and engaging in continued rehabilitation (occupational therapy [OT], physical therapy [PT], and rehabilitation engineering). In addition, failure to perform needed positive health behaviors is met with consequences within the game environment. For example, players

who do not cath will see a reduction in points/abilities while leaving a stink trail behind them, which will additionally impact the mood and reactions of non-player characters (NPCs). Table 1 provides a more comprehensive review of the health behaviors required and how these are conceptualized within the game.

Table 1. Health Mechanics and Required Health Behaviors

Issue to Manage	How to Manage and Monitor	For Planning	Consequence
Skin	Pressure reliefs -every 30 minutes monitored via timer	Recognize need for pressure reliefs at regular intervals	Skin breakdown and decreased health
Bowel	Bowel program - once every 1-2 days monitored via timer	Need bathroom	Bowel accident, Stink cloud, Decreased health, Embarrassment/increased stress, Impaired communication
Bladder	Cathing - once every 4-6 hours monitored via timer	Need correct supplies ("cath kit") or need bathroom	Bladder accident, Stink cloud, Decreased health, Impaired communication
Stress	Monitor stress levels, make time for stress-relieving activities, and enhance cognitive flexibility- monitored via POS	Monitor regularly, notice relationship between stress, health and communication, and take time for stress-relieving exercise	Decreases health, communication, cognitive flexibility and ability to navigate
Cognitive Flexibility; Resilience	Enhances problem-solving, attention, and memory- monitored via POS	Manage Stress, play memory mini-game/Dr. Shrync's cognitive test	Impacts health, impacts resistance to Chillax 3000

Issue to Manage	How to Manage and Monitor	For Planning	Consequence
Health	Perform all health behaviors, improve fitness, manage stress, and increase cognitive resilience - monitored via POS	Optimize all behaviors and carry needed items in backpack (including food and cath kit)	Impacts stress, impacts energy / fatigue, and impacts ability to accomplish tasks
Energy/ Fatigue	Improve fitness, manage stress, and perform all health behaviors - monitored via POS	Optimize all behaviors and pacing of behaviors	Impacts navigation, influences ability to accomplish tasks
Fitness*	Eat healthy food, avoid unhealthy food, drink water, exercise/ engage in physical therapy - monitored via POS	Purchase / Pack healthy food in backpack, and go to PT[c] to exercise	Impacts energy and health

SCI Hard focuses on enhancing skills, encouraging positive health behaviors, and empowering people within their own environments, recognizing that people have different resources and abilities. By teaching skills to better manage health, it was hypothesized that this serious game should not only reduce the occurrence of complications but also promote higher levels of social integration and quality of life. In particular, playing the game should allow players to recognize the consequences of their behaviors, as actions and inactions are tied to visible results and substantial changes in statistics.

The Game and Story

While early on players are engaged in learning game dynamics, monitoring health, and adjusting activities to optimize performance, as they gain skill and increase in level they are

asked to participate in a larger quest, more reminiscent of adventure and role-playing games (RPGs). In this world, Dr. Shrync, the psychologist they encounter in inpatient rehabilitation, is determined to control the population through his mind-controlling device, the Chillax 3000, and take over the world. Individuals with SCI, because of their increased awareness of their surroundings and heightened problem-solving abilities, are a threat to him and his plans. Because of this, Dr. Shrync crafts a plan to use the everyday animals of the town to do his bidding and hinder or even harm the character and those close to him or her. After defeating several such minions and achieving a specific ability level in task management, players are invited to join an underground resistance of healthcare professionals who are working to thwart Dr. Shrync's evil plans. If the player accepts, they are sent on a secret mission that will allow them to save the world, which they will be able to complete only if they continue to perform the health behaviors required to maintain their health.

The game consists of four levels and more than thirty mini-games that focus on the development of particular skills. At the start of each new game, players have the opportunity to customize their character to suit them, including changes to their sex, outfit, and skin tone (figure 1). Additional information about the story for the game and its various levels can be found in table 2.

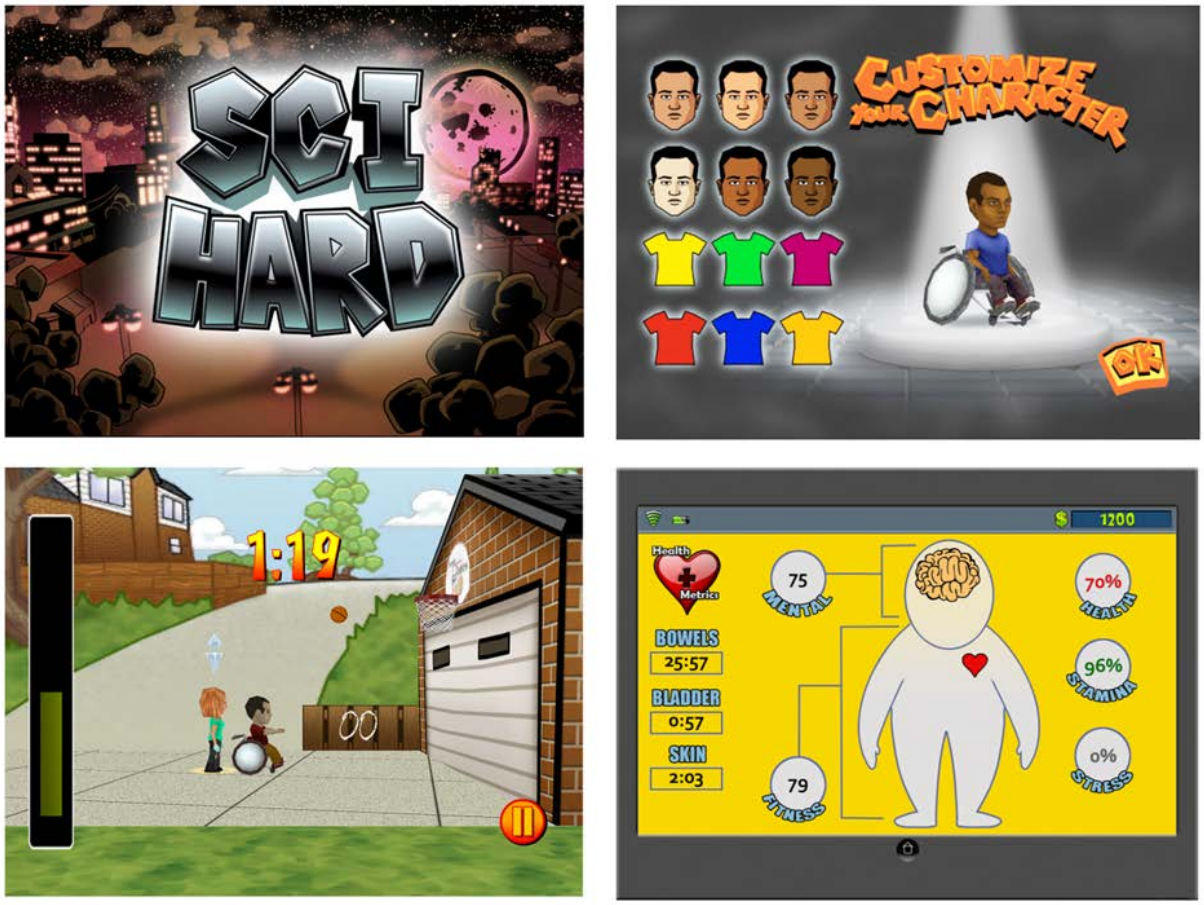

Fig. 1. Screen shots from SCI Hard. *Upper left:* Title screen. *Upper right:* Customizing the character. *Lower left:* Basketball mini-game. *Lower right:* Health metrics screen.

Table 2. Storyline and Skills Reinforced at Each Level of SCI Hard

Level	Story/Plot line	Self-management Skills Reinforced
1	Players wake up in a rehabilitation hospital and discover that they have a SCI.[a] They must learn the basics of navigating and managing their health before they can leave the hospital.	Self-monitoring Organization
2	Players work with their rehabilitation team to manage their health and communicate effectively, as well as manage a complex social situation.	Communication Problem solving
3	Players have the opportunity to learn to drive and purchase an accessible van while trying to get to a local club to see their friend perform, while navigating motor skills and social interactions.	Integration of skills to increase independence
4	Players must unravel Dr. Shrync's complex plot to rule the world and defeat him in a final high-energy showdown that requires the use of skills learned so far while managing their health.	Multitasking Self-monitoring

Discussion

Methodology for Evaluation

Two separate evaluations were part of the development of SCI Hard, assessing first the beta version and then the final version of the game; feedback from the beta version was used to refine the game prior to the final version. While SCI Hard was initially developed for individuals with traumatic SCI between the ages of 16 and 24, the decision was made to allow individuals from the ages of 14 to 29 and those with spinal cord dysfunction (including spina bifida) to participate in the second evaluation phase in order to assess its applicability to a broader audience.

Participants and Procedures

This study was approved and monitored by the Institutional Review Board at the University of Michigan and took place between May 2015 and March 2016. Participants were

eligible to participation in the study to evaluate SCI Hard if they were between the ages of 14 and 29 and had traumatic SCI or a spinal cord dysfunction. Exclusion criteria included having significant cognitive impairment, undergoing current hospitalization or rehabilitation, or experiencing significant emotional distress or suicidal ideation at the time of the screening or assessment.

All participants were instructed to play the game as often as possible over the following two weeks but, at a minimum, to try to complete all levels at least once. Individuals who participated in the first evaluation did so from a borrowed device with the game already uploaded onto it; individuals who played the final version did so after downloading it onto their own mobile device. During the two-week period for game play, participants were reminded to play the game via email or phone calls. Follow-up assessments occurred approximately two weeks later and were conducted either in person or through online surveys with technical assistance available through telephone support if needed. Participants received a $50 incentive for completing the study or a prorated payment for partial completion.

Feedback About the Game

All participants were asked specific questions about how often they used the game, what level they achieved, and specific game-related challenges, and then were asked to provide feedback about their experience. They were also questioned about the extent to which they viewed the game as relevant to individuals with SCI and potentially useful in learning to manage their condition.

Results

Eighteen individuals 16 to 29 years old enrolled the study. However, three did not complete the follow-up assessment and one was not able to access the game; for this reason, the

data of only fourteen individuals are included in the section. Of these fourteen participants, eight played the beta version of the game and six played and evaluated the final version. Participants who completed the study ranged from 18 to 29 years of age (mean age = 24.43; sd =4.20), were evenly split between males and females, and were primarily non-Hispanic White (84.6%). Most participants had traumatic SCI (n=11), though two had spina bifida and one had another type of impairment. The level of injury ranged from high-level tetraplegia to low-level paraplegia with most (92.9%; n=13) reporting some ability to use their arms and hands.

In describing their game-playing habits, most reported playing electronic games on a hand-held gaming device (including a smartphone) either every day or a few times a week (71%). In contrast, a majority said they never played games on a computer (57%) or a tablet (57%), while only 29% reported regular use of a game console. Participants were most likely to indicate that they played shooter games, racing games, sports games, puzzle games, and computer board or card games (all 42.9% or n=6). Few participants endorsed playing music games, arcade games, RPGs, or Massively Multiplayer Online (MMO) games.

Subjective evaluations about SCI Hard were sought from all participants. Table 3 provides a summary of this information. Overall, players liked the game and found the story line relatable and/or educational, though this was not universal. When asked their opinions about specific game elements, most participants gave positive feedback about the graphics and art, the dialogue, the characters, and the mini-games. Reactions to the music and plot were a little more varied. Six of the fourteen participants felt that the game changed the way they thought about their SCI or managing their health; however, thirteen felt that the game would be beneficial to individuals with a new SCI, particularly within the first two or three years after SCI (four responses) and newly injured kids, teens, and young adults. Other groups that were identified

included “Anyone. People that don't have SCI could get a better understanding of what it's like to have it.”

Table 3. Subjective Evaluation Responses of Participants for Each Version

Question	Response: Beta (n^a = 8)	Response: Final Version (n = 6)
How often did you play the game?	Ranged from a couple times a week to almost every day.	Ranged from a few times a week to every day.
What kept you from playing it more?	Glitches within the game or other activities.	Busy schedules, disinterest, health issues, and technological problems.
How far did you get in the game?	Non-completion (62.5%) and game completion (37.5%).	Non-completion (66.67%) and game completion (33.33%).
Did you play the game through more than once?	Yes (25%) No (75%)	No (83%) Yes (17%)
What did you like about the game?	Game relatable and educational.	Characters, mini-games, and health management devices.
What did you not like about the game?	Dialogue, technological problems, lack of guidance within the game, and tasks related to chores.	Some of the characters or sequences within the game, parts of the game difficult to figure out.
What did you think of the graphics/art?	Ranged from “Good” to “Love it.”	Ranged from “Good” to “Love it.”
What did you think of the dialogue?	Ranged from “Okay” to “Amusing” to “Goofy.”	Ranged from “Good” to “Comical” to “Could be improved.”
What did you think of the characters?	Responses ranged from “Good” to “Funny” to “Cheesy.”	Responses ranged from “Good” to “Colorful” to “Cheesy.”
What did you think of the mini-games?	Ranged from “Fun” to “Frustrating.”	Ranged from “Fun” to “Frustrating.”
What did you think of the music?	Ranged from “Good” to “Annoying.”	Ranged from “Good” to “Annoying.”
What did you think of the plot?	Ranges from “Liked it” to “Did not understand it.”	Ranged from “Liked” to “Disliked.”

Question	Response: Beta (n[a] = 8)	Response: Final Version (n = 6)
Do you think that the game changed the way you thought about your SCI or managing your health?	Yes (12.5%) Somewhat (50%) No (37.5%)	Yes (33.3%) Somewhat (33.3%) No (33.3%)
Who do you think could benefit most from playing the game?	Adolescent SCI patients, newly injured individuals, non-SCI population who want to learn about the experience of individuals with SCI.	Adolescent SCI patients and newly injured individuals.
Did you have any other comments or concerns?	Technological problems, need for additional guidance, and desire to see more positive message.	Technological problems, need for additional guidance (less frequency than the beta version).

Conclusions

SCI Hard was developed using an iterative, community participatory approach to facilitate or reinforce the application of self-management skills in a format tailored to the preferences, learning styles, and skills of adolescents and young adults with SCI/D. Results provide preliminary evidence that this serious game was feasible to implement — even at a distance — and acceptable to the target population. In addition, while the game was evaluated only with individuals with SCI/D of varying lengths and severity, responses from this group identified others who may potentially benefit from playing. While most agreed that the game would likely be most helpful to adolescents and young adults with relatively new spinal cord injuries, it was also noted that playing SCI Hard could provide anyone with new insights into the complicated health behaviors and other challenges associated with managing a SCI.

However, the results also made it clear that SCI Hard was not universally liked. Some participants found particular aspects — or even the entire game — annoying. Similarly, some healthcare providers may not care for the way particular characters or disciplines are represented.

While personal preferences are always going to influence how free time is spent, it may be that for some individuals with SCI, playing SCI Hard may need to be assigned or prescribed in the manner described for other educational games. At a minimum, having the opportunity to discuss the game and gameplay elements with rehabilitation providers may allow for expectations and stereotypes to be better articulated.

The evaluation contained in this paper focused on describing its usability, enjoyment, and relevance. The next step is to evaluate its short-term impact, including the extent to which playing the game results in improved knowledge, problem solving, and adjustment to disability and/or increased self-efficacy. The final and most important step, though, will be to determine the game's long-term influence on improving health behaviors, reducing secondary conditions and healthcare costs, and improving community integration.

Importantly, though, this study describes an innovative way that we can leverage technology to supplement existing practices and to enhance outcomes. Health care is changing and rehabilitation also needs to change and adapt. Technology can allow for scalable solutions that can be tailored to particular groups and issues.

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