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An Exploratory Analysis of Game Telemetry from a Pediatric mHealth Intervention

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Abstract

Pediatric obesity is a growing epidemic, with unhealthy eating habits and poor physical activity being major contributors. While video and mobile games have been shown to have a positive impact on behavior change in children, the mechanisms underlying game play that impact outcomes of interest are poorly understood. This research aims to examine the impact of a novel mobile gaming app on the design of behavioral interventions by learning from the rich and unique game telemetry generated from a randomized controlled trial of the app use by school children. In this exploratory analysis, we extract a partial dataset to build and analyze chronological sequences of game plays to understand key patterns in the game mechanics that players utilize as they navigate the game, and possible implications of the results.

Keywords:

Pediatric Obesity; Mobile Apps; Game Telemetry Analysis

Introduction

This research is motivated by the need to explore some of the challenges and related opportunities at the intersection of the rising epidemic of pediatric obesity worldwide [1], healthy eating and physical activity related behavior modification challenges in children [2], and the growing role of gamification and learnification on mobile devices in the lives of these pediatric digital natives [3]. While there is some early evidence of the positive impact of video games on healthy eating behaviors in children [4], the mechanisms underlying these improved outcomes are yet to be understood. To design appropriate interventions in the game environment for children's behavior formation and change, we need to learn more about the underlying patterns of player behaviors evidenced during gameplay, the goals they are trying to achieve with the game, and their overall gameplay experiences.

In this exploratory study, we analyze game telemetry to understand user interactions from playing Fooya, an iOS/Android based mobile App that has been shown to improve the nutrition-health of children through virtual reality-based immersive mobile gaming which uses Artificial Intelligence to achieve personalized behavior reinforcement [5]. We analyze the interactions with the game choices made by the players in a randomized controlled experiment in a middle school setting. Learning from and associating game playing behaviors with known factors affecting unhealthy eating behaviors and the players' food choices at the end of the game may provide new insights into the complex interactions between game playing and health behavior changes necessary to design more impactful interventions via games on mobile devices in order to improve pediatric overweight and obesity rates.

Background

Pediatric Obesity

Obesity is an increasingly common epidemic in children. The growing pediatric obesity rate worldwide has serious health consequences such as cancers, diabetes, asthma and shortened life span as well as higher healthcare costs [1; 2; 6]. While there are many factors that contribute to overweight and obesity, diet decisions are a leading cause [1]. Unhealthy eating habits and poor physical activity is a major contributor to the growing obesity epidemic [7]. There is significant ongoing focus on addressing the risk factors and moving the population to a healthier lifestyle through health education/ communication and motivation. Establishing healthy eating habits early in life is important because childhood habits are predictive of those in adulthood [7]. There is a clear need to identify effective methods for improving dietary intake and physical activity habits earlier in life that are acceptable to children.

Games on Mobile Devices

Games have been shown to have positive impact on children [8]. Many children spend several hours a day playing video games [3; 4], mostly on mobile devices, a platform through which they can learn about health in a fun and enjoyable way. This may be one approach to address the multi-faceted challenge of the pediatric overweight and obesity epidemic [9, 10].

However, a critical barrier to progress in the field is the lack of understanding about the mechanisms underlying games that impact outcomes of interest. Video games include many levels of challenges, imaginative virtual worlds, and the opportunity to navigate them in distinct ways, alone or in teams [11]. The appeal of discovery may be a strong motivator of these games to some players while others may enjoy the competitive or collaborative nature of the game. Gamification is the studied, thoughtful, and creative application of game design elements to engage the player [11; 12]. Games with a highly directed experience and tiered set of tasks can challenge and motivate players. While much is known about game design, recent research has highlighted the gap in understanding the specific mechanisms that link the game playing behaviors with observed outcomes so that game design as well as re-design can be informed through evidence based knowledge and practices [12-14].

Game Telemetry

Large volumes of data are routinely collected during game play and analyzed in simple ways. Game developers nowadays remotely and unobtrusively monitor every aspect of a game, allowing them to accumulate large amounts of data of the player-game interaction over extended time periods [15]. One type of data collected is the actual clicks made by the player as they navigate the game, called game telemetry. At the current time, this clickstream data is used to analyze questions such as whether players are entering the game or not, if they are dropping out early or late, if they are playing the game for a while and then dropping out at some distinct step, and so on. This type of feedback is made available in real time so that game developers can track usage and player engagement that have implications for success of the game.

Learning from clickstream/telemetry data.

This data is a valuable source for developers and game designers to guide decision-making throughout the game design process, to understand player movements, reduce production costs, or uncover bugs, among others. At the same time, the increasing popularity of online gaming has led to in-game statistics to improve player experiences by providing performance summaries and comparisons to others playing the game. There is now a growing field of game analytics, some of it focused on using telemetry data to discover and communicate meaningful patterns in data in the context of game development and game impact [15]. For example, identifying which paths result in the longest game time and what game features engage players in these paths require methods to learn paths from the detailed telemetry data and then examine the features that define these paths in unique ways. Hence new approaches that leverage advanced statistical machine learning methods that can learn from large volumes of multiple streams of high dimensional data have the potential to facilitate the analysis of patterns in telemetry data streams.

Impact on design of behavioral interventions.

There is a growing recognition of the need for more refined strategies for designing behavioral interventions for complex health conditions that allow incorporation of personalized evidence-based knowledge and increased use of data and information technology to improve health outcomes [16]. Researchers have suggested that behavioral science can provide new insights to make key design decisions by the designers of serious video game for health-related games. Future research needs to investigate the most effective ways to achieve the dual goals of fun-ness and seriousness [14]. The availability of highly granular game telemetry from mobile video games promoting healthy behavior changes, enhanced with data about food habits and choices, provides a unique opportunity to develop data-driven, statistically rigorous, models and methods for learning from this data to provide insights for designing interventions in mobile video games for diverse health conditions that can be further evaluated in actual decision settings [17]. For example, real-time game data can inform designers where players are having difficulties in the game and can potentially modify the design, perhaps in real time, to improve that experience.

Methods

Mobile gaming App

fooya!™ is a novel mobile gaming, iOS/Android based App that has been shown to improve the nutrition-health of children through virtual reality based immersive mobile gaming that uses Artificial Intelligence to achieve personalized behavior reinforcement [5]. fooya!™! has been shown to deliver statistically significant outcomes, with respect to food choices, during randomized-controlled clinical trials conducted at the Baylor College of Medicine's Children's Nutrition Research Center [5]. Researchers at Kaiser Permanente Medical Group were involved in analyzing longitudinal impact on over 1000 children at multiple sites over a weeklong period during the ExxonMobil Summer Science Camp [18]. These findings are significant as increasing awareness and self-efficacy are the first steps to achieving health behavior change [19]. Outcomes from these and other trials have shown consistently positive trends, while also exposing opportunities for product feature development, enhancement and continuous refinement. This novel approach to behavior design aims to pave the way for targeting lifestyle disease prevention by enabling lifelong healthy lifestyle habits. This may be achieved by instilling healthier preferences during early childhood and the formative years of life.

Through game design that achieves a psychological state of flow for deep cognitive engagement, fooya!™ aims to increase awareness and induce greater self-efficacy. Underlying health models enable story telling surrounding topics of metabolic equilibrium and health balance pertaining to the user's Avatar. fooya!™ harnesses multiple core game mechanisms that deliver a single player and multiplayer experience to achieve behavior design through a social, mixed reality experience. Game compulsion loops guide users while getting harder over time, which makes users think more deeply and strategically, the more they play. The core engagement mechanism in fooya!™ adaptively engineers user experience moments that deliver a highly contextual message through a method of experiential discovery, as the result of learnification – a design thinking method of embedding and harnessing contextual learning within core entertainment. Based on a hypothesis derived from pediatric neuropsychology, fooya!™ was developed to deliver innovative therapeutic entertainment to make healthy behavior change incredibly fun for the children.

While the experimental studies with fooya!™ have shown promising results as a result of innovations through a Digital Vaccine candidate technology based on Neuropsychology to reduce the risk of lifestyle diseases [20], they fail to explain the mechanisms underlying these improved outcomes. To design appropriate interventions for behavior formation and change via video games, we need to learn more about the underlying mechanisms that link game playing to healthy/unhealthy eating behaviors. Attracting and maintaining a child's attention may be the biggest contribution of video games to health-related behavior change, but this has not been demonstrated [13]. Game playing is a complex process. The automation of analysis and visualization of game telemetry is an opportunity for Artificial Intelligence based personalization for specific users.

Data

A rich and unique data set was generated via a randomized controlled trial of the use of fooya!™ by school children. With ethics board approval and informed consent from participants, a research study was conducted to assess the awareness levels among urban Indian children regarding diet and lifestyle behaviors and evaluate the influence of the fooya!™ digital vaccine intervention, among school-age children in India. Specifically, the study objectives were to quantify the effectiveness of fooya!™ on health awareness around eating right and physical activity; find out the current diet and physical activity among urban children in India and the factors that affect them; and assess the extent of their awareness about eating right and physical activity. Using a pre-test, post-test research design, a total sample of 90 students from 3 urban schools between 10-11 years of age, equally split between control and treatment groups and randomly assigned, participated in the study. A structured questionnaire first collected demographics, food habits, self-efficacy in selecting healthy foods, nutritional knowledge, and use and frequency playing video games using validated measures from the literature. Students in the treatment group played the mobile game for up to 20 minutes, while the control group played a board game. Once the game playing was completed, the participants were offered a choice of snacks to assess behavioral health outcomes, and a post-test questionnaire was administered to collect information similar to the pre-test questionnaire. All telemetry data associated with the actual game play by the children was also gathered and de-identified for the purposes of the study.

In the game, children make several decisions with split second timing, such as food choices, destroying bad/unhealthy food robots using the bad foods that are thrown at the player, and saving themselves. If the children collect good/healthy foods, they are in *fit-zone* for a while, which shields them from bad food robots. Throughout the game, telemetry data is collected across different game levels about bad foods thrown by robots at the player, good foods collected by the player during the game, how many times children read 'nutrition facts' and of what kind of food, for how long they were in *fit-zone*, and how many times they were hit by bad food robots. The activities in each level also sequentially influence activities in the next level, potentially affecting children's behavior enough to influence their real food choices eventually. By finding patterns in this game playing data, we can investigate the dominant and rare navigation patterns and their paths to the food choices of children. Eventually, a feedback loop in the game design may be needed to also influence them at the right time to make better and healthier food choices. Figure 1 shows a screen shot of the game with all the mechanics detailed above.

Figure 1 – A screen shot of fooya!™

Our exploratory analysis utilized 2 primary sources of data:

(1) Gameplay measurement variables from clickstream data that included:

- Total gameplay time, measuring game engagement: Per level and Overall
- Total levels per session, measuring performance outcomes
- The extent of customization or difference from the stock character will be assessed to indicate the extent of vicarious experience/self-modeling. The characteristics considered include: character gender, character clothing (female), character clothing (male), and so on.
- Average movement per minute, measuring game engagement; Average time: Per level and Overall
- Setting type (by level) for contextual analysis
- Type of nourishing food "consumed" (e.g., broccoli, cauliflower)
- Frequency of type of nourishing food "consumed" (e.g., broccoli, cauliflower)
  - Hit to Miss ratio (Accuracy of throws) measuring performance outcomes: Per level and Overall
  - Number of times hit, measuring performance outcomes: Per level and Overall
- Net calories accumulated per level, measuring performance outcomes
- Type of ammo obtained, measuring vicarious experience
- Active selection of healthy power-ups, measuring vicarious experience, including type and frequency: Per session and level
- Type of robots encountered, measuring performance outcomes, including number met and ratio of number destroyed and number met

(2) The second source of data is the demographic data on the players, meta data on the game plays such as playing time, completion status, and so on, and the food choices of the children at the end of the game.

In this exploratory analysis, we extracted a small subset of the de-identified game play data of 14 children who participated in the study in July-August 2016. We conducted a simple descriptive analysis of game mechanics to better understand the flow and critical features of the game in order to design advanced analysis of the play sequences of the full cohort in a future study. In particular, we compare the game sequences of the 14 players in their first level with that in the final level and summarize these differences, though the small sample size limits generalizability of the results.

Analysis

Construction of Event Sequences

Each player's telemetry data, described earlier, was processed and encoded according to a feature labeling scheme by which every possible feature currently utilized in the game by the players was assigned a distinct feature label. These labeled events are ordered chronologically based on their recorded timestamps. These chronologically ordered sequences of events represent the game playing experience of each player. Both game mechanics, which are techniques refined by designers to engage users in gameplay such as intangible rewards and recognition for achievements, and game dynamics, which include techniques designed to affect the pace of gameplay, such as time limits or countdowns, are used in fooya!™.

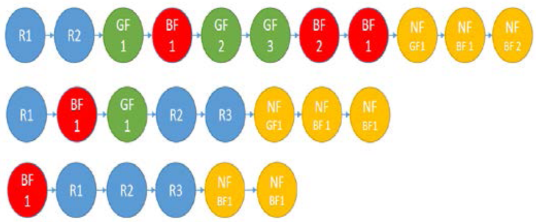

Figure 2 – Example Game Play Sequences of 3 Children

Figure 2 displays the game play sequences of 3 children, illustrating both game mechanics and game dynamics. Each path represents multiple levels in the game, with each level comprising different types of interactions. The blue boxes represent robots that are destroyed by the player, the green boxes represent the good/healthy foods they grab during the game and the red boxes represent bad/unhealthy foods that attack the player which they need to dodge. Lastly, the yellow boxes represent the nutritional facts read by the child. Across different players and their levels of play, the number, type and sequences of nodes can greatly vary and is reflective of their game engagement.

For example, in sequence 1, the player begins the game by destroying 2 robots, then grabs a healthy food item, is attacked by a bad/unhealthy food item, grabs 2 good food items, is attacked again 2 bad food items and ends the level by reading nutrition facts about three different foods, one of healthy type and 2 of unhealthy type. Sequence 2 of the second player includes fewer actions within the same time limit, while sequence 3 of player 3 has the least and with no access to good food items or nutrition facts on good foods.

In this preliminary study, we first conduct a descriptive summary of the game mechanics and dynamics that are demonstrated by the sequences. Together, this analysis will provide some early insights into the patterns that are utilized by the players as they navigate through the game's mechanics, reflecting game playing processes and its flow.

Results

The 14 players were equally divided in terms of gender, and the ages of the players were very similar since they were all recruited from the same grade at school. A descriptive summary of the game telemetry displayed in Figure 3 shows that some children played only 3 levels of the game, while others went much farther, with 1 child playing 12 levels of the game over the same duration as the others, though on average, males and females played similar number of levels. Figure 3 also summarizes the game mechanics used by the players in the first and final levels of the game. The aim was to examine changes in the access to different mechanics between these levels by all players, and the differences, if any, by gender. We observe that there is a significant increase in the use of different mechanics between the first and final levels, indicating that the players may be learning to play the game better as they navigate the levels. Furthermore, the differences between male players and female players also increase, particularly in the case of bad foods and robots destroyed.

		Lower bound	Upper bound	Average: Total	Average: Males	Average: Females
	Number of levels	3	12	8.5	8.9	8.1
First Level	Nutritional Facts	1	11	3.6	3.6	3.6
First Level	Good Foods	0	4	1.6	2.3	0.9
First Level	Bad Foods	0	14	2.6	1.6	3.6
First Level	Robots Killed	0	14	5.2	8.3	2.1
Last Level	Nutritional Facts	0	6	1.9	1.9	1.9
Last Level	Good Foods	0	6	2.3	3.3	1.3
Last Level	Bad Foods	1	47	12.7	18.9	6.6
Last Level	Robots Killed	1	23	11.1	17.0	5.3

Figure 3 – Summary of game mechanics in the first and final levels of game play across all 14 players

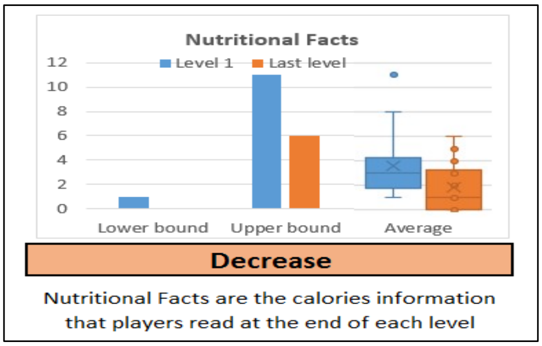

Figure 4 – Change in average number of Nutritional Facts looked up by the players in first and final levels of their games

Figures 4, 5, 6 and 7 display the changes in each of the game features of fooya!™ between the initial and final levels played. Interestingly, fewer Nutritional Facts are looked up by the players, as shown in Figure 4. This may likely be due to the increasing familiarity that the players feel regarding the nutritional content of the foods they encounter which decreases their interest and motivation in looking up this information over and over again, but this needs to be verified across other levels of the game and the post-intervention survey responses. This can be useful as early feedback for game re-design that may require new features to capture and retain the interest of the players in a critical component of the game's mechanics, which is about teaching nutritional facts associated with good and bad foods in a fun way.

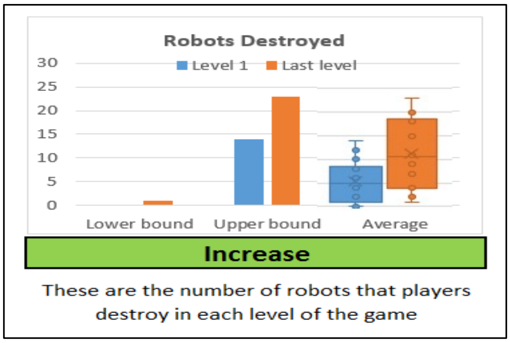

Figure 5 – Change in average number of Robots destroyed by the players in the first and final levels of their games

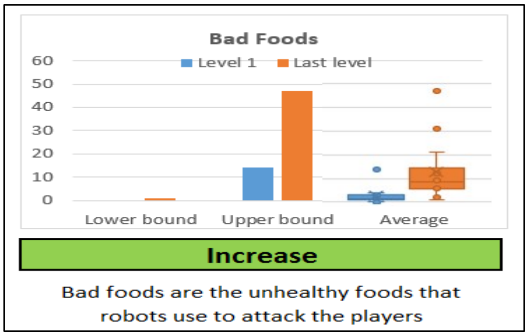

Figure 6 – Change in average number of unhealthy foods used to attack players in the first and final levels of their games

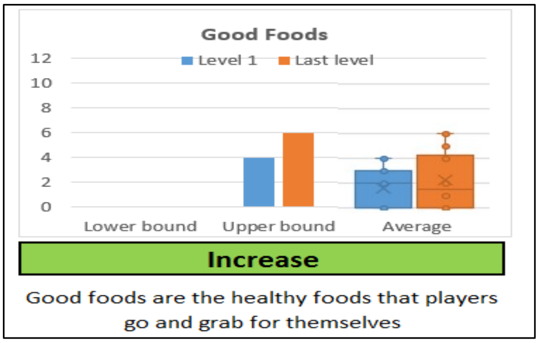

Figure 7 – Change in average number of healthy foods that players grabbed in the first and final levels of their games

Figure 5 shows almost a doubling in the average number of robots destroyed by the players between first and final levels of their games, indicating that the children are learning to identify the bad foods thrown at them and respond to it quickly to save themselves. Consistent with this implication, Figure 6 shows that there is also an increase in the average number of bad foods utilized during the games, so the players are actively engaging with the game mechanics as they proceed from first level to the final level. Finally, Figure 7 displays an increase in the average number of good foods selected by the players, likely implying that there may be some learning occurring regarding healthy vs. unhealthy foods.

Discussion

This exploratory study examines some preliminary game sequences of children playing a novel healthy eating related mobile app to gain a better understanding of the use of game mechanics. However, how this may be correlated with food choices at the end of the game is yet to be investigated. The current analysis provides some early indications of players' interests in using the different game mechanics built into the game and the need to design additional methods to display nutritional information that continues to engage the players over all levels of the game. Due to the limited number of participants analyzed in this study, it is not possible to generalize the results at this time.

Conclusion

Analysis of game play is challenging due to the multiplicity of game features, mechanics, dynamics and other characteristics. Future research will investigate the use of additional data from a larger set of participants to explore all aspects of game play and their associations with decisions made by the players regarding their food choices and the likely reasons for them based on survey responses. The potential impact of these decisions on pediatric obesity and health costs is a longer term investigation of interest.

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