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DEPARTMENT: APPLICATIONS

# Scaling the Virtual Fitness Buddy Ecosystem as a School-Based Physical Activity Intervention for Children

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*Childhood obesity is a growing concern as it can lead to lifelong health problems that carry over into adulthood. A substantial contributing factor to obesity is the physical activity (PA) habits that are formed in early childhood, as these habits tend to sustain throughout adulthood. To aid children in forming healthy PA habits, we designed a mixed reality system called the Virtual Fitness Buddy ecosystem, in which children can interact with a virtual pet agent. As a child exercises, their pet becomes slimmer, faster, and able to play more games with them. Our initial deployment of this project showed promise but was only designed for a short-term intervention lasting three days. More recently, we have scaled it from a pilot grade study to a 9-month intervention comprised of 422 children. Ultimately, our goal is to scale this project to be a nationwide primary prevention program to encourage moderate to vigorous PA in children. This article explores the challenges and lessons learned during the design and deployment of this system at scale in the field.*

Physical activity (PA) is a critical determinant of health and well-being in children[1] and PA habits established in childhood often extend into adulthood.[2] In recent years, interventions based on digital technology have shown promise in enhancing both children's PA and enjoyment relative to traditional interventions.[3] Guided by social cognitive theory[4] and self-determination theory,[5] we designed a system that uses a virtual pet to encourage children to engage in higher levels of PA through enhancing their sense of autonomy and competence with respect to PA, as well as cultivating a relationship between the virtual agent and the young user. This system was first used in a 3-day pilot study at a local summer camp.[6] The results from this study showed promise; the children who worked with a virtual pet and activity tracking device were excited to play with their pet and performed higher levels of PA on average compared to a control group of their peers, who received an activity tracking device and a syncing computer without the virtual pet. For the next phase of this research,[7] we were interested in the efficacy of the virtual pet intervention once it was scaled up from this 3-day intervention at a single site to a 9-month intervention across 20 sites. We named this new project the Virtual Fitness Buddy (VFB) ecosystem. While it shared the goal of the original study of encouraging children to engage in increased PA with the assistance of the virtual pet, the new project presents an expanded scope for longitudinal observation at scale in the field to study the practicality of the approach. We also expanded the capacity of the VFB ecosystem to provide social support to children by enabling parents to communicate with their children, encouraging them to achieve their PA goals. This further aligns with self-determination theory by incorporating social support (i.e., relatedness) to encourage the internalization of PA habits.

However, the scaling up process was not as simple as adding more content (e.g., games to play with the

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**FIGURE 1.** (Left) Early version of the VFB kiosk. (Right) Updated version of the VFB kiosk for this study.

pet). Many design decisions had to be made and implemented on both the hardware and software levels, including improvements on the usability of the ecosystem. The goal of this article is to describe our current version of the VFB system and the design decisions we made along the way. These decisions often had to be made with various tensions in mind, such as maintaining high scientific rigor of our research study versus designing an engaging application given the practical challenges and limitations. We also discuss some of our lessons learned upon implementation of this system in the field.

## HARDWARE DESIGN

The VFB ecosystem is designed for research to be implemented at YMCA afterschool sites with minimal assistance from site staff and for building an engaging application to promote continued user adherence with the intervention. With this in mind, there were several features we sought to include from the outset. As the name suggests, the focal point of the design is the virtual pet. Ideally, the children who use our application should feel as if they are physically present, or "really there," with their virtual pet and interacting with them similarly to how they would play with a real pet at home. Both virtual reality and mixed reality applications lend themselves to this end. However, we also wanted our system to be standalone and easy for multiple children to use in succession in a group care setting with minimal burden for the staff assisting our team on the project. It needed to be easy to set up and children needed to be able to "walk up and play" with little to no setup.

### Kiosk Design

Given these design goals, we chose a mixed reality approach, featuring a large-screen display, a computer, and a Microsoft Kinect (see Figure 1) placed on a kiosk, which we assembled and modified in-house. The original version of the kiosk used during the pilot study[7] featured a 55-inch display with a 1920x1080 resolution and 60-Hz refresh rate along with an Alienware Aurora R5 with a Nvidia GTX 970 graphics card and Intel core i5-6400-Hz processor. Our current version of the kiosk features a 50-inch display with a 1920x1080 resolution and a 60-Hz refresh rate along with a Dell Inspiron 5680 with a Nvidia GTX 1060 graphics card and Intel core i5-8400-Hz processor.

In addition to improved aesthetic qualities, the current version of the kiosk needed to be mobile, durable, and secure like the original version of the kiosk. Its mobility enabled site staff to roll it out when it was time for the children to use it and put it away in a secure location at the end of the day. Additionally, the kiosk and application both turned on automatically when a single cord was plugged into power. Both features reduced the burden on the site staff.

The kiosk was designed for long-term use, meaning it needed to be sturdy and protect the equipment housed within it. As shown in Figure 1, the kiosk is comprised of a commercial TV-stand with a locking metal cabinet. The original version of the kiosk, as shown on the left side of Figure 1, was used for both the 3-day summer camp[6] as well as an additional pilot at a single afterschool site.[7] We modified the current version of the kiosk to include a custom wooden front panel (see the right side of Figure 1), which has been used for all subsequent studies. This panel allows for radio waves to pass between a user's activity tracker and the computer contained within the ventilated cabinet. Both the Kinect and a touchscreen were placed in this front piece, as it restricted unwanted adjustments of the Kinect's rotation compared to the previous version of the kiosk that had the Kinect placed on top. The success of this approach has been evident; the current version of the kiosk has withstood two 9-month long studies across 10 different sites without failure or damage. We will refer to the samples in these two studies as cohort 1 and cohort 2. These cohorts represent two different sets of children and school sites, where the studies were conducted during two different years, starting during the fall school semester (August) and ending during the spring school semester (May). The sites were selected from a pool of local schools that offered YMCA afterschool programs.

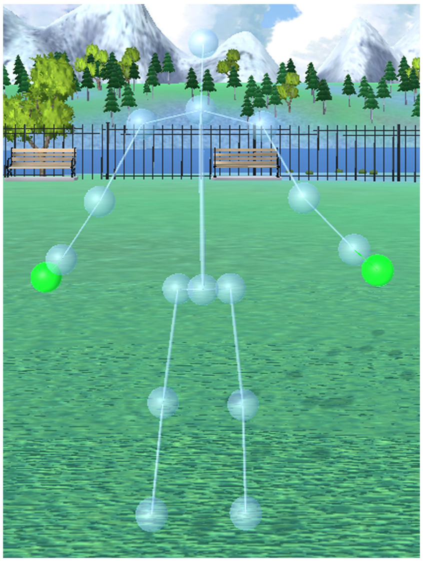

**FIGURE 2.** Example skeleton that is generated using data from the Kinect.

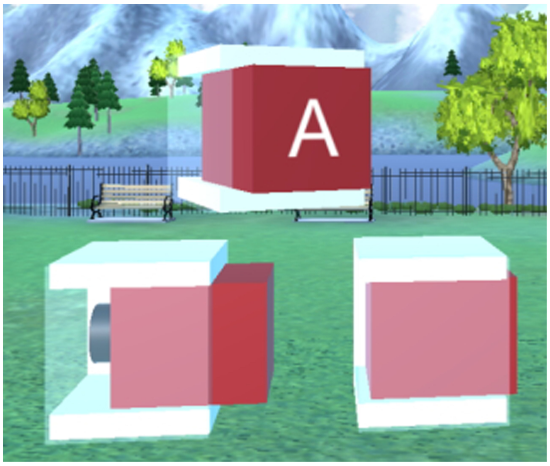

**FIGURE 3.** Example of a 3D keyboard key. It works similarly to a real-world keyboard, wherein the red cube is pushed in and triggers when it "presses" on the black cylinder.

Using the Kinect served two purposes. First and foremost, it avoided the perception of the kiosk as pure "screen-time." Screen-time is normally associated with sedentary activity, but the kiosk is a stand-up interface that requires significant body motion. In addition, the Kinect allowed children to use their bodies to directly control an avatar in the virtual environment (see Figure 2), helping to establish a sense of copresence and mutual awareness with the pet. Furthermore, using this body-based interaction, we designed gestures used for performing tricks with the virtual pet. These gestures are similar to those often taught to dogs in real life, such as "sit" and "roll over." We also designed various motion-based and reality-based games for children to play with their virtual pet, such as fetch (see the "Motion Games" section for more details). Lastly, the Kinect was solely used to control the VFB application. It was not used to collect motion data in regard to tracking a child's PA. To track a child's PA, we used a dedicated PA tracker (see the "PA Tracking Hardware" section for more details).

A major hurdle for this project was designing the user interface interaction. In the past, we tried a hover-based system,[6] in which children could control an on-screen cursor by moving their hand. Once they moved the cursor over their desired selection, they would hold that position for a few seconds to "click" the button. However, children struggled to use this system reliably, despite prior evidence suggesting that it works well with adults. We then tried a 3D, physics-based keyboard-like interface (see Figure 3), in which the avatar's hands would be used to push buttons. In pilot studies,[7] this approach also failed due to difficulty controlling the button placement relative to the real-world user location. Child participants found these to be cumbersome to use as they had to ensure they were standing in the correct location to reach buttons, and the lack of strong depth cues on the screen made this difficult.

Ultimately, we added a 10.1-in LCD capacitive touchscreen with a 1280×800 resolution as shown on the right side of Figure 1. This touchscreen added some privacy with respect to displaying a child's PA data and made it easier for children to make menu selections. However, we kept the screen small to ensure that children would still be motivated to spend the majority of the interaction being active while playing with their pets. Through observations, we found children were able to learn and to use this touchscreen system more quickly and more consistently compared to our hover and keyboard-like interfaces. Thus, this touchscreen approach was used for all subsequent studies after the pilot,[7] including the current version of the kiosk (see Figure 4).

## PA Tracking Hardware

In addition to the VFB kiosk, another key hardware component was the PA tracker. While this project was intended for research, we also needed this project to be scalable to several sites with many children. This meant that we needed a PA tracker that was reasonably accurate, affordable, and intended for long-term use with children. Research grade trackers are

**FIGURE 4.** Child using the current VFB system while other children in the study watch.

**FIGURE 5.** Two of the fitness trackers used during the VFB project, from left: Fitbit Ace 2 and Fitbit Inspire.

expensive and require specialized equipment to charge and download PA data. Therefore, we opted to use Fitbit activity trackers (see Figure 5), which met the above criteria and also have significant brand recognition, which excited many of the children even before we mentioned a virtual pet. These Fitbit trackers tracked the children's PA data throughout each day. Additionally, these Fitbit trackers were used as a way to login at the kiosk.

To use the PA data from these Fitbits, we needed to synchronize children's recent Fitbit data with the kiosk. Fitbit provides a free smartphone app that will sync a user's Fitbit data to their Fitbit account. However, to rely on this in our study would have meant that users needed to repeatedly login and logout of their personal Fitbit accounts and the VFB system each time prior to playing with their pet. This method of syncing presented a problem for our study as it would have limited children's engagement and the VFB's scalability. Although their VFB kiosk login into the kiosk required only a four-digit code, Fitbit logins require both an email and password. Not only would this be more difficult to remember and tedious to do every time prior to playing with their pet, it also would require another device built onto the kiosk. Fortunately, the Fitbit system also allows for computers with an attached USB-dongle to passively sync encrypted tracking data from any nearby device. Thus, we included this feature in the kiosk. Prior to playing with their pet, children needed to wait to receive confirmation that their data was recently synchronized with Fitbit servers. This meant they would have their most recent activity recorded and ready to use while playing with their pet.

However, this syncing process proved to be the most pervasive problem throughout the VFB project. This syncing method worked well during our lab tests, but we had constant issues with syncing Fitbits in the field. Originally in our pilot and first cohort of sites, we had our kiosk constantly syncing all nearby Fitbits in the background. This would lead to the Fitbit dongle crashing over time. We suspect this was due to the field sites being a more dynamic environment than our lab, where children could run out of range in the middle of syncing. Fortunately, this issue could be corrected by restarting the kiosk, but we were unable to completely resolve this issue for our first cohort of study sites.

To remedy this for our second cohort of sites, we tried a new method where we only synced the Fitbit of the child logging into the VFB system. This time the Fitbit dongles no longer crashed. However, we found that children's Fitbits would sometimes disconnect while syncing, even if they did not move away from the kiosk, leaving the Fitbit to "think" it was still connected to the computer. This proved to be more frustrating for the children because they either had to wait five minutes or soft reset their Fitbit to continue the syncing process to play with their pet. As with our previous method, we were unable to fully resolve this issue in the deployed system. Nevertheless, we found that the children used the system and enjoyed playing with their virtual pet despite these syncing issues.

The syncing problems have been a major issue for our studies as they have prevented our participants from being able to play with their pet consistently, which is key for promoting healthier PA habits. Thus, for future studies, we will attempt a different approach. Specifically, we intend to provide participants with a tablet to sync their Fitbit at home using the provided Fitbit app. We also will no longer be requiring a recent Fitbit sync to play with the pet. This means our participants could simply play with their pet using our kiosk and then sync their Fitbit activity at home with a dedicated device. Instead of daily updates to the pet's

**FIGURE 6.** Children could customize their virtual pet's breed, collar, tag, and hat. Examples of these customization options are shown in this figure.

stats, we will switch to weekly updates so children will have time to review their PA with their parents and be rewarded for that activity on a regular basis. Pilot studies of this approach have proven promising, with no reports of difficulty syncing the devices.

Based on our experience across two years of using Fitbit PA trackers, we recommend using the Fitbit app for syncing. This means less time is used to develop a similar system for a given project. Additionally, Fitbit's app can be installed on multiple devices, allowing those devices to sync the Fitbit passively when it is nearby.

## SOFTWARE DESIGN

In addition to designing and implementing the kiosk, we also designed the VFB application. To build this application, we used the Unity 3D game engine[a] using C# for scripting. To pull the PA data from a child's Fitbit, we used the open-source software Galileo.[b] Lastly, to pull the skeleton data from the Kinect, we used the Kinect SDK from Microsoft.[c]

Unlike the kiosk design process, there were several tensions we needed to balance with the development of the application. The application needed to be designed with the project's research foci in mind. However, to achieve the research goals, we needed the application to be engaging and fun to play. Thus, we needed to strike a balance between the needs of research and the need for an engaging game. In the following sections, we will elaborate on how these tensions manifested and describe the main features of the VFB application.

### Virtual Pet and the Gamification of PA

Gamification of a behavioral intervention introduces tensions because although gamified elements can initially induce desired behaviors, failure to internalize the activated behaviors will lead to reliance on extrinsic rewards, which has been known to lead to failure in sustaining the change in behavior after the extrinsic rewards stop.[8] Therefore, the gamification of a system needs to be complemented with ways for users to internalize the changes they are making in their behaviors for long-term change to take place. With this in mind, our design choices were driven by tenets of self-determination theory,[5] which is a psychology theory which posits that humans are motivated by universal psychological needs, including a desire for autonomy (performing behaviors under one's own volition, rather than through external compulsion), competence (feeling self-efficacy when completing a task), and relatedness (seeking interpersonal connection to other people).

In our current version of the application, the virtual pet is an animated dog that children can customize and name (see Figure 6). When a child logs into the VFB app, they can name the virtual pet. They can also select the breed of their virtual pet and are given a default collar and tag. As shown in Figure 6, children can further customize their pet by purchasing collars, tags, and hats from our virtual store. Additionally, they can buy virtual toys, such as a tennis ball, from the shop. These toys and customization options are bought using points earned by setting and meeting PA goals. This meant children were rewarded for setting

[a]unity3d.com/get-unity/download
[b]github.com/benallard/galileo
[c]developer.microsoft.com/en-us/windows/kinect/

**FIGURE 7.** Size progression of the virtual pet from the smallest pet (left) to the largest pet (right).

and meeting goals that were appropriate for their self-determined PA goal for the day. They could also earn a set amount of points every day for simply wearing their Fitbit and visiting their virtual pet. By doing so, we incentivized activities that were necessary for our study. Finally, by providing the ability to set their own goals, we provided each child with a sense of autonomy in line with social cognitive theory,[4] as they have control over how much PA they intend to complete. This gives them agency to determine the pace of the intervention.

In addition to rewarding children with points, we wanted to reward them for engaging in different types or intensity of PA. To achieve this, we chose to give the virtual pet attributes, including fitness and stamina. We mapped these attributes to different game elements. Fitness impacts a pet's body size and speed. Body size, as the name suggests, affects the visual size of the pet (see Figure 7). As a child's pet becomes healthier, they visibly become slimmer. Fitness also affected the pet's running speed, increasing the speed as the pet decreased in size. A faster pet could play more games in the time given to children to play with their pet. It also increased the maximum score they could earn in certain games, as their pet would be able to reach the target object faster. Finally, stamina impacted how long a child could play with their pet each day, ranging from 60 to 240 seconds. This increased the amount of games and tricks a child could perform with their pet each day.

For the current version of the VFB system, we moved from having these attributes increase based on different PA metrics, such as active minutes and steps, to a "level up" system, where a level is an ever-increasing value that improves a pet's stats and allows a child to unlock new games at certain values. This level up system simplified how each pet's attributes increased. Rather than needing to remember that body size and speed were increased by active minutes while the amount of time they could spend with their pet was increased by steps, they simply need to complete a set amount of PA. Once they reach the amount of PA needed to level up, each attribute would increase by a set amount plus a random value. This randomness was included to add variation to each level. This meant when a child leveled up their pet, it would be a surprise to see how many points these stats increased. In addition to increasing these attributes, leveling up their virtual pet also unlocked various minigames, which will be further discussed in the following section.

In summary, we recommend considering the goals of the system when designing the rewards given to participants. For our system, we wanted to reward children for engaging in PA in general, meeting PA goals, and completing certain tasks each day, such as wearing their activity tracker and visiting their pet. As a result, we designed two different reward systems. For the first system, we did not want to lock children out of improving their pet if they did not reach goals. Thus, we added the ability to improve the pet through PA in terms of its characteristics, such as size and speed, and unlocking new games. This meant children could see tangible changes to their pet and the system based on their completed PA, regardless of goal attainment. For the second system, we wanted to reward children for meeting goals and completing tasks that were required for study participation. Thus, we designed the points and shop system in a way that the children could improve the experience of the system by buying customizations and toys without preventing them from playing with their pet because they had not met their PA goals. We recommend making these reward systems simple and easy to explain so that participants can quickly grasp what is required of them and how to impact their experience of the system.

## Motion Games

Not only could our participants customize their virtual pet, but they could also play with them. Using the Kinect, we designed several motion-based minigames. These games ranged from simple tricks (e.g., sit, fetch) to a timed balloon popping minigame (see Figure 8). Designing these games was more difficult than we had anticipated. One of the big problems we faced was determining the intent of the child. To address this, we added a touchscreen, as shown on the right side of Figure 1. This addition allowed us to know which game or trick the child wanted to play.

However, the touchscreen did not help when it came to throwing, for example. We did not know when the child intended to release the ball. We designed a throwing gesture, but it was not very accurate. However, it did mimic real-world throwing and, thus, was intuitive for children to use. We

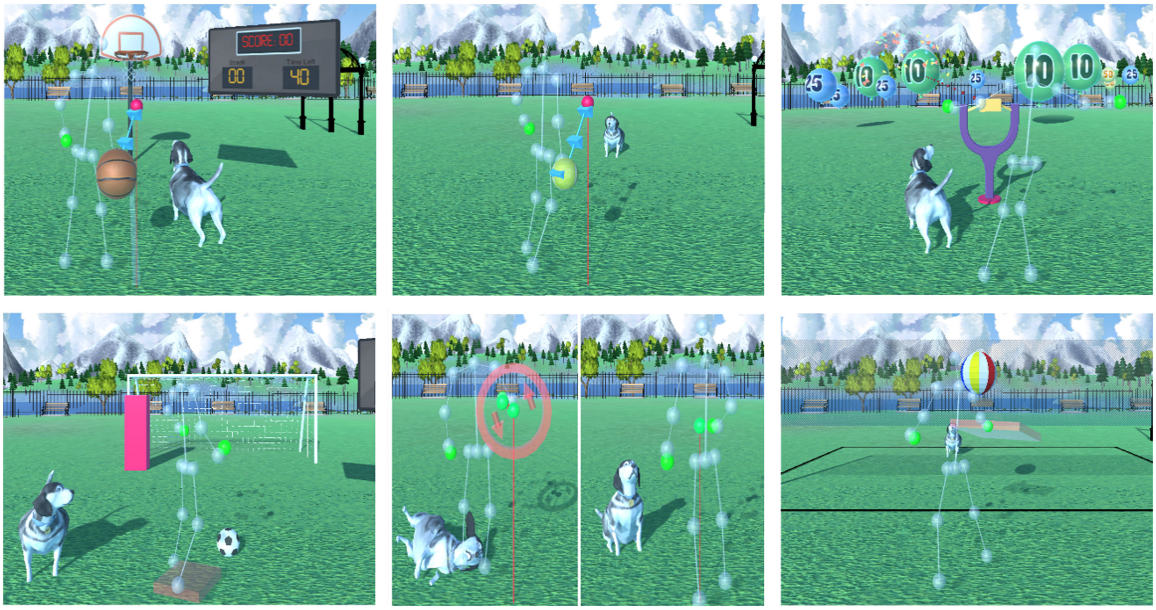


**FIGURE 8.** Examples of the various minigames that can be played with the virtual pet. From top left the games are basketball, fetch, slingshot, soccer, tricks (roll over and sit), and volleyball.

addressed this accuracy problem in two ways. The first way was to design a slingshot (see Figure 8), where the pouch snapped to the child's hands when they were brought close together. They could then aim by moving their hands behind the slingshot. Finally, they would indicate that they were ready to fire the slingshot by moving their hands apart. This minigame was a good complement to the "fetch" trick in that children found it substantially easier to aim at targets. However, this solution did not address the accuracy problem for the basketball game, as it still relied on the throwing gesture.

Thus, the second way we addressed the throwing accuracy problem was with a "shot zone" (see Figure 8). The shot zone allowed the children to signify when they wanted to initiate a throw or trick by placing their hand inside the shot sphere. Then, they would pull their arm back and move it around to aim using the arrows. Finally, they would "push" their hand through the sphere to throw the ball. These shot zones were used for both the basketball and fetch minigames (see Figure 8). Although this method was accurate, it was not intuitive and proved difficult to use in the field, where we were not available to successfully explain how the shot zone worked.

Another mechanic we designed was a paddle, inspired by a ping pong paddle. The paddle acted as an extension of the child's hand or foot and allowed them to hit the ball more easily than trying to hit the same ball with only their skeletal hand. We implemented this mechanic in both the volleyball and soccer minigames (see Figure 8). This approach proved quite intuitive, if not immediately usable, as it did not require the children to activate the paddles to use them as they did with the shot zones.

As previously mentioned, we decided to use the shot zone mechanism for trick gestures as well. Originally, we had voice activation for tricks, but we found in the field that the environments were very noisy. The ambient noise made it hard for the speech recognition system to convert text accurately. Thus, we switched to activating the tricks using a button on the touchscreen. To add gestures, we included the shot zone mechanic so the children could signify when they wanted to start the trick and when they wanted to end it. The designed gestures were intended to mimic real-world gestures used to train a real-world pet (see Figure 8).

In summary, for designing motion games, we recommend designing motion-based mechanics then building games around those mechanics. These mechanics, such as throwing or using the paddle, could be used as a basis for multiple games. Additionally, all the minigames were designed to be quick, short experiences designed around a single mechanic. As such, these games were simple, easy to learn, and quick to play, which meant that we did not create a long line of children at the group-based school environments waiting to play with their pet.

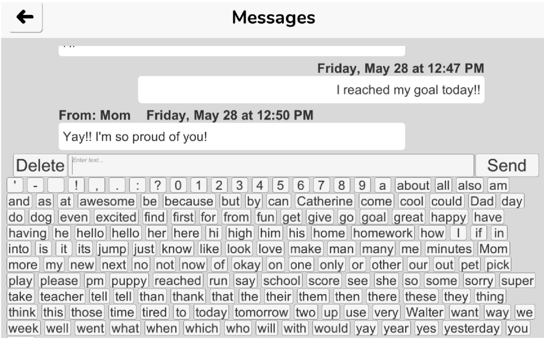


**FIGURE 9.** Example of our messaging system in which children can text their parents from a preset word list.

## Social Interactions to Encourage PA

The third main component of the VFB app is the social component, where children are intended to interact with each other and with their parents. Interaction with their peers came in the form of PA leaderboards, personal game high scores, and, due to the large display, seeing what games and items their peers had unlocked. The PA leaderboards were setup on a site-by-site basis. Each leaderboard consisted of the following four categories: lifetime active minutes, weekly active minutes, lifetime wear days, and weekly wear days. Wear days are days where a child had at least 1000 recorded steps. Our idea with the leaderboard was to encourage children to both wear their Fitbits and to be active every day. We did not want to discourage children who may not have started the study with high levels of PA. Thus, we added the weekly active minutes and wear days so that all children started with a clean slate each week.

The game high scores encouraged children to keep playing the games and to try to achieve the best score. These scores were only displayed once a child logged into the system and selected the game. Thus, these scores were more for personal motivation but could also be shown easily to their peers as desired, creating a sense of competition.

Finally, we also included a messaging system (see Figure 9) that allowed children to text with their parents. We wanted to foster a communal effort towards achieving PA goals. Part of this involved parental support for reaching their PA goals. The messaging app provided select words for the child to choose to send, including their name, their pet's name, their parent's name, and several popular words related to the VFB system. These messages were sent to the phone number their parent provided us, so the parent could respond in real time by texting the child back. In addition to this messaging system, we provided an interface that sent notifications to the parent when the child logged in to the system. As such, if a child did not have their Fitbit charged or left it at home, the child could send their parent a quick message to help remind them to charge it or wear it the next day.

All these social components are in line with social cognitive theory[4] and self-determination theory,[5] which include supportive environments and social relationships as important components in eliciting long-term behavior change. With the leaderboards embedded in a group-care setting at afterschool and local YMCA programs, we helped to establish a supportive environment conducive to PA such that the children are encouraged to be more active by seeing and hearing their peers engaging in and excelling in PA. With parents being able to message their children, they provided social support and encouragement as children reached their PA goals.

When implementing social elements in virtual systems, we recommend considering different ways in which the system can help construct a supportive environment for users. For our system, we wanted to foster a sense of communal support. Thus, we created an open communication channel between parents and children to freely text each other. We also included leaderboards for children who were more competitive, allowing them to see how well they were doing relative to their peers. These leaderboards also let them see their peers' PA performance. This in turn likely motivated them to continue using the system.

## At-Home Version

We are actively developing an at-home variant of the VFB system using iPads in place of the kiosk model, where the iPad is used as the main display and interaction device with the virtual pet (see Figure 10). As of this writing, we are conducting a feasibility study using this at home version with a third cohort of children and their families. For this version, we allow parents and siblings to contribute to and interact with the family's virtual pet instead of a single child from the family as in previous version of the VFB system. Each family can complete a family review through our website, where they can see each member's contributions to the virtual pet as well as their PA. These family reviews are required to increase the stats of the pet, unlock new games, earn points to spend in the shop, and earn PA goal trophies that increase in size and add an animated version of their virtual pet at higher PA goals. Our goal with this requirement is to motivate


**FIGURE 10.** Example interface of the iPad-based VFB system.

children to complete these reviews in order to unlock new ways to customize and play with their virtual pet while giving parents an opportunity to check their progress. In addition to the reviews, families have access to YMCA wellness coaches. These coaches are intended to help a family review their PA data and help them plan their PA goals. Leveraging these reviews and allowing the family to contribute to the pet, parents should be able to engage more with the study and help guide their children to set and meet their PA goals.

Thus far, we have implemented six games into the at-home system: an agility course, basketball, frisbee, soccer, trick memory game (see Figure 10), and volleyball. For these games, we wanted to retain motion-based controls similar to the Kinect version so that we were not encouraging sedentary play. Examples of these motion controls include using the iPad as a paddle during volleyball to hit the ball to their virtual pet and moving the iPad to aim their shot during basketball to achieve the desired shot angle. Alongside these games we have added study-wide score leaderboards, where participants can see high scores from other study participants if their parent has opted into including their scores as part of this leaderboard. We have also included leaderboards for an individual participant's high scores as well as their family's high scores. It is our goal with these new games and leaderboards to provide several ways to promote continued engagement with the virtual pet. We designed the leaderboards to appeal to competitive participants, who may be more motivated to keep improving their virtual pet to maintain their high score ranking. We designed each game to have a different core interaction mechanic to provide varied playing experiences over time. These varied experiences are intended to motivate participants to continue to engage with their virtual pet to try new games or ways to play.

Regarding these new games, it has been much easier to modify the existing virtual pet app with the iPads (as opposed to the kiosk) for two major reasons. First, because we can constantly monitor the iPads, we can issue updates to the virtual pet app for every iPad used in our study at once as opposed to either traveling out to or remoting into each kiosk to manually update the app. This makes adding more content or adjusting how a mechanic works much easier, allowing us to provide additional games or items throughout the study to maintain engagement. Second, it is much easier to generate new games or game modes for the iPad compared to the Kinect. For each Kinect game we designed, we had to ensure there would be enough physical space to complete the game for each site. With the iPad version, as long as there is space to stand up, there is enough space to complete the games. We have also found it is easier to design and implement games on the iPad compared to the Kinect since we no longer need to design mid-air control schemes.

With these lessons learned from this iPad version of the VFB system, we intend to adjust our kiosk-based system if/when we can return to the afterschool setting. For example, instead of our current version of the kiosk, we could deploy a system of smaller kiosks with monitored iPads. This would allow us to generate similar content for both the afterschool experience and the at-home experience. It also may be easier for site staff to monitor and set up since the iPads would need less physical space compared to our current kiosk. Alternatively, we could maintain the kiosk as is and provide two different experiences for children in the afterschool program: one in which they use their bodies to play fetch or perform tricks using the kiosk and the other in which they can have a more one-on-one experience with their virtual pet at home. This new iPad version of the VFB system allows more children to engage with the VFB system given that they no longer need to be a part of an afterschool program to interact with it. It also allows the children to have more time to bond with and engage with their virtual pet given that they do not have access to the kiosk over the weekend. Additionally, it allows us to explore potential augmented reality games and different ways to play games to engage these children with the VFB system in addition to our current VFB kiosk. Lastly, we believe that this at-home VFB system will provide more randomness compared to the sites from the kiosk-based studies. As a result, this randomness may allow us to better explore the impact of the VFB system on the PA outcomes without the additional factor of varied site engagement.

## CONCLUSION

Data analysis for the VFB ecosystem is ongoing as of this writing. Preliminary results show that the latest version of the VFB system likely resulted in a moderate though significant increase in moderate to vigorous PA compared to the control condition (PA tracker with a syncing computer). However, differences in the site environment and implementation quality at the different afterschool sites may have confounded the observed PA outcomes. For example, some site directors and staff were more rigorous with the implementation protocols, encouraging children to meet their goals and use the system regularly. Other sites were more hands-off and set up the system for the children to use each day.

Preliminary results comparing the effects between cohorts 1 and 2 indicate that the VFB ecosystem had an increased effect on moderate to vigorous PA among the children in cohort 2 compared to cohort 1. Additionally, from on-site observations, we have found that each subsequent iteration of the VFB system has been more successful in engaging the children. The children were excited about the system and enjoyed using it despite the issues we had regarding Fitbit syncing. Given the preliminary results, this increased engagement with the ecosystem may have led to the increased levels of PA in cohort 2. However, we have not explored how system engagement relates to this increase in PA. This exploration will allow us to parse out the impact of implementation effects (e.g., logistics, buy in from staff) from the treatment effects (e.g., impact of the VFB ecosystem).

Regarding future directions, we intend to continue adding other minigames, such as an agility obstacle course, as well as additional features, such as a public virtual dog park in which children can interact with each other along with their pets. These additions would further extend the life of the VFB system, create a more engaging experience, and add avenues of social support as children use the system. By adding games, we give children more options to play every day and try something new while engaging in additional PA to unlock these new features. The added social support from peers and other participating families will help children internalize the positive aspects of PA, so that PA becomes an established long-term lifestyle choice for children. Given that we have a working system, it will be easy to update and incorporate these new ideas.

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