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Assisting Children Action Association Through Visual Queues and Wearable Technology

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Assisting Children Action Association Through Visual Queues and Wearable

Technology

A Thesis by

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Submitted in partial fulfillment of the requirements for the degree of

Master of Science

in Computational and Data Sciences

October 2016

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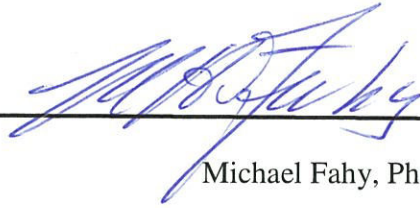
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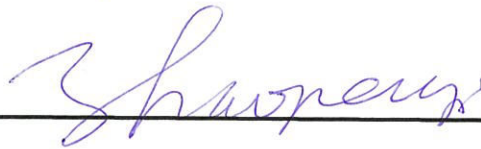
The Thesis of Anthony Young is approved.

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Michael Fahy, Ph. D

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October 2016

Assisting Children Action Association Through Visual Queues and Wearable
Technology

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ACKNOWLEDGEMENTS

I would like to thank my family, Erik Linstead, Michael Fahy, Peiyi Zhao, the Chapman University Computational Sciences Faculty, Ria Tirona, Chirstin Walder, and the rest of the Autism Management Platform Team.

ABSTRACT

Assisting Children Action Association Through Visual Queues and Wearable
Technology

by Anthony Young

Autism Spectrum Disorder makes it difficult to for a child communicate, have social
interactions and go through daily life. Visual cues are often used to help a child associate
an image with an event. With technology becoming more and more advanced, we now
have a way to remind a child of an event with wearable technology, such as a watch. This
new technology can help a child directly with the Visual Scheduling Application and
various other applications. These applications allow children and their families to be
easily able to keep track of the events on their schedule and notify them when an event
occurs. With the Autism Management Platform and related website, a parent can easily
create events to help a child throughout the day. The child can associate an image with
events, allowing for a clearer understanding of what to do when an event occurs.
Wearable technology has become a new way to interact with the user in a very
unobtrusive manner. With this new technology, we can help associate a visual event to a
child's schedule and interrupt when needed to help make the child's life easier on a daily
basis.

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Chapter 1

Introduction

The objective of this thesis is to help children diagnosed with Autism Spectrum Disorder (ASD) through the use of visual schedules with the Visual Scheduling Application (VSA). A visual schedule uses images, symbols, and photos to communicate a task or activity. The Autism Management Platform (AMP) system consists of a central database with various platforms that end users use for interaction and is used to connect the VSA and AMP. AMP is a tablet application where parents or therapists enter medical or daily activity information that may be helpful for the child such as a tantrum timer or a video recording. One example of information is the child's schedule for the day. Another platform, the VSA then takes the scheduling information entered and displays it in the form of a visual schedule for the child with ASD to use. ASD research has shown that visual schedules are a useful communication tool for the child since the child's brain is more visually oriented. Along with the application, data is collected to help further analyze the effects the visual schedules may have on the child.

The primary goal of AMP and the VSA is to assist children through their everyday lives along with caretakers and parents. The visual schedules are an effective way for the child and therapists or parents to communicate while taking advantage of modern technology. Design decisions in the VSA and its associated applications are built to be versatile. Any updates or additions of features require no major overhaul, and the apps will still maintain their essential design and functionality. For example, if there is

new technology designed specifically for children with ASD, it can be incorporated into the AMP system without any major changes required. Google Glass and Android Wear are just two examples of such technologies that were incorporated into the AMP system.

AMP began as a class project for a Chapman Software Engineering Course. The professor, Erik Linstead, has a daughter diagnosed with Autism and he saw how technology could be used to help improve outdated medical research that still largely relies on the use of pen and paper. The project was created to show how the information written with pen and paper could be incorporated into an app. The course taught the students how the software development life cycle worked by allowing them to go all the way through from application and process to development and finally to testing. AMP was designed to utilize a multitude of features and allow for easy integration in the future. After the course was over, several students realized the potential of AMP beyond a class project. The students decided to continue the project and see what additional adjustments could be made to further develop AMP.

In 2014, The Chapman AMP team participated in the App Jam at the University of California, Irvine (UCI). The competition, where Chapman and UCI partnered together, tasked participants with creating an application to help children diagnosed with Autism. Participants had two weeks to design and build an app of their choice which would help children with ASD. For example, one group used the Xbox Kinect in an effort to improve children's motor skills. They created a game where the players had to move around in order to grab specific points on the screen designated as objectives. The AMP team decided that adding visual schedules to the existing AMP system would be an

appropriate task for such a competition. After researching visual schedules, the team

worked on designing the visual schedules and what would be the best way for the

schedules to integrate into the AMP system along with the recently available Google

Glass.

Over the summer of 2014, Android Wear was introduced to the world. It revolves

around the idea of wearable computing. Wearable computing is where a piece of

technology worn on the person is integrated into everyday life without causing any

inconveniences or intrusions. With Android Wear, visual schedules could be extended to

run on the Android Watch platform. During the App Jam competition, the team

introduced visual schedules with wearable computing through Google Glass but found

that it wasn't a great fit. Android watch technology seemed like a much better fit and

more compatible for a younger audience due to its lower cost and durability.

Chapter 2

Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is defined by a wide range of behavioral and communication deficiencies developed in childhood. ASD is difficult to diagnose due to the wide range of symptoms. There is no known cure, but there are various methods and treatments available to assist a child to improve communication and behavioral skills. One useful method is to use visual cues as a way of improving communication. With such associations, the child will learn to connect a picture to an event, helping to remind them of previous experiences or learning. For an autistic child, day to day activity can become very hectic and even a small change in schedule can help to cause a temper tantrum. A schedule with visual cues is a very helpful way for the child to handle changes in schedule thus creating a useful communication tool with the autistic child.

2.1 Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is established through the various characteristics developed in childhood. These include persistent deficits in social communication and social interaction across multiple contexts and restricted or repetitive patterns of behavior, interests, or activities. For diagnosis, symptoms must be present in the early developmental period, and cause clinically significant impairment in social, occupational, or other important areas of functioning [4]. Since ASD covers such a wide spectrum, diagnosis and treatment are difficult.

However, one of the most profound mysteries of autism has been the remarkable ability of most autistic people to excel at visual spatial skills while performing so poorly at verbal skills [21]. Children with ASD typically understand and think much easier in visual contexts. A word such as "run" might mean nothing more than a string of letters to the child, but the picture of a person running will trigger memories and past knowledge of the action. Knowing that Autistic children are visual learners, using visual cues to help a child tie words to actions is a very useful method in helping the child learn and develop.

2.2 Treatment

There is no known cure for Autism, so the best option is to minimize the symptoms and increase daily functioning. Early diagnosis, intervention, and treatment can go a long way in minimizing the effects of Autism on a child's life. A study was conducted on forty-eight children diagnosed with ASD comparing the effects of early intervention and treatment with a control group who received treatment at a later time. The results showed that children who received early intervention showed significant improvements in IQ, adaptive behavior, and autism prognosis. These results show the importance of early detection and intervention to help children with ASD [24]. With such improvement, the child may have the symptoms minimized enough such that school can be attended normally without significant assistance.

The most effective treatment for Autism is called Applied Behavioral Analysis

(ABA) [24]. This treatment option includes speech therapy, physical therapy and

occupational therapy, all which aim to minimize the impact of ASD. The goal of ABA

therapists is to help children to communicate and interact with the world around them.

Since children with ASD have difficulty expressing their thoughts and feelings, a tantrum

might be the only way a child to display frustration before therapy. After ABA treatment,

a child may learn to create a drawing as a more effective way to communicate their

feelings for others to understand.

One effective strategy utilized in ABA is to take advantage of the child's visual

strengths. This can be done by visually representing information with pictorial and

written cues. A study by Thiemann revealed that this kind of intervention was effective in

increasing social communication skills of the children with Autism [22]. For example, a

child may not understand and remember that after eating dinner, it is time to shower.

However, a picture of a dinner plate followed by a picture of a shower can be a way to

communicate with the child and teach them what to do after dinner.

Much more research is needed to further understand ASD. There are many ways

to identify if a child has Autism and its related characteristics, but there are no definitive

medical procedures or tests available determine if a child has ASD. It is important to find

an effective way to diagnose ASD early in development, as earlier diagnosis along with

earlier treatment can help a child with Autism significantly. Various treatments such as

therapy are the best-known way to treat Autism, but there is no known cure. Visual

schedules are just one example of a communication tool to help a child, but further research is needed to help improve functioning and communication.

2.3 Life with Autism

A day in the life of a child with ASD can be very hectic. One moment the child can be calm and receptive, and then in the next moment be aggressive and need much more special attention. An important factor for a child is routine, as any sudden change from familiarity can be an adventure [2]. For example, every day a child may have a routine of breakfast, speech therapy, lunch then playtime. If the schedule changes and one day speech therapy comes after lunch, the child can become frustrated and confused, leading to a temper tantrum.

Living with children diagnosed with ASD requires a lot of understanding and patience. It is extremely difficult to keep a consistent routine and not knowing how the children may react to any changes makes life even more difficult. Additionally, there is the struggle of trying to find a balance between letting them be independent while giving them the special attention they may need.

It is established that individuals with ASD demonstrate a variety of impairments in executive functioning, which make it difficult for them to function on their own without assistance. Particularly, it is difficult for people with ASD to deal with new situations and processing complex information, which are common for functioning in

everyday life [15]. To alleviate the sudden shock of new situations occurring, Visual

Schedules were created to help alleviate some of these troubles by notifying children

early of upcoming changes. The child is able to see upcoming events and potential

changes much earlier by looking at the schedule. The fact that the child can utilize this

tool without heavily relying on a parent or caretaker creates a sense of independence.

Chapter 3

Visual Schedules

A visual schedule uses images, symbols, and photos to communicate a task or activity. There are many types of visual schedules, but they usually include a time, picture and a few words to describe the activity. These visual cues are what the child uses to associate with a task. The cues are then laid out in chronological order to create a visual schedule, which highlights current and future activities. It is important to remember children with ASD are visually oriented. Showing them how to do something is a much more viable option since telling them what to do can lead to confusion. Visual cues provide an effective way for the child to communicate with family or physicians, as they play to the child's visually oriented brain.

3.1 Studies with Visual Schedules

There is clear evidence that visual schedules help a child with ASD go through his or her day. For example, they help the child by decreasing the anxiety of having to figure out what is next on the agenda. This sense of structure provides children with a sequential order to do things, therefore creating relief and a further sense of independence [10]. The child no longer needs to ask someone else what event is going to happen next. The schedule will show the child what needs to be done after the current activity, so they can proceed without having to rely on parent or caretaker, therefore, creating a sense of independence. For example, after dinner, the child needs to shower. The child sees the

shower visual cue and can go off and shower alone without any further assistance or reminders.

The visual cues in a schedule also allow the children to worry and focus less on what may happen next. Autism Speaks suggests that some children with ASD are anxious and act out when routines change or they are in unfamiliar situations. Visuals can help them understand what to expect and will happen next and also reduce anxiety [4]. When an unexpected change happens, anxiety can take over and sometimes even aggressiveness. Visual schedules create structure and prepare the child with an earlier notice for any future events, therefore reducing the likelihood of undesired outcomes.

For example, a child notices while looking at his schedule that there is a speech therapy session later on in the day, which is not part of his typical routine. Normally he would have an anxiety attack since he feels unprepared for the change, even if speech therapy is something familiar to him. Instead, he checks his visual schedule which gives him early notice of any changes in his schedule. He will notice that the speech therapy event in the schedule is different from what normally happens during that day. Fortunately, the event includes a visual cue for the child that can be associated with previous events. The term "speech therapy" might be confusing and unfamiliar to him, but the image of a talking man will remind him of his usual speech therapy sessions. The child will know that in speech therapy, first he must go to the doctor's office and prepare to leave home. The visual schedule presents information in an understandable format along with early notification of when changes occur.

3.2 Designing the Visual Schedule

Visual schedules may seem like a good idea, but it would not be very useful if they caused more confusion and anxiety for the child. Designing visual schedules is a difficult task since one must decide how best to represent the necessary information while minimizing any potential misunderstandings.

Visual schedules present the concepts of activities and time by using pictures, words, and other visual elements to describe what will happen, in what order and where. Many experts advocate the "First this…Then this…" structure [14]. The designs of each event would have a picture and some words to help with the association.
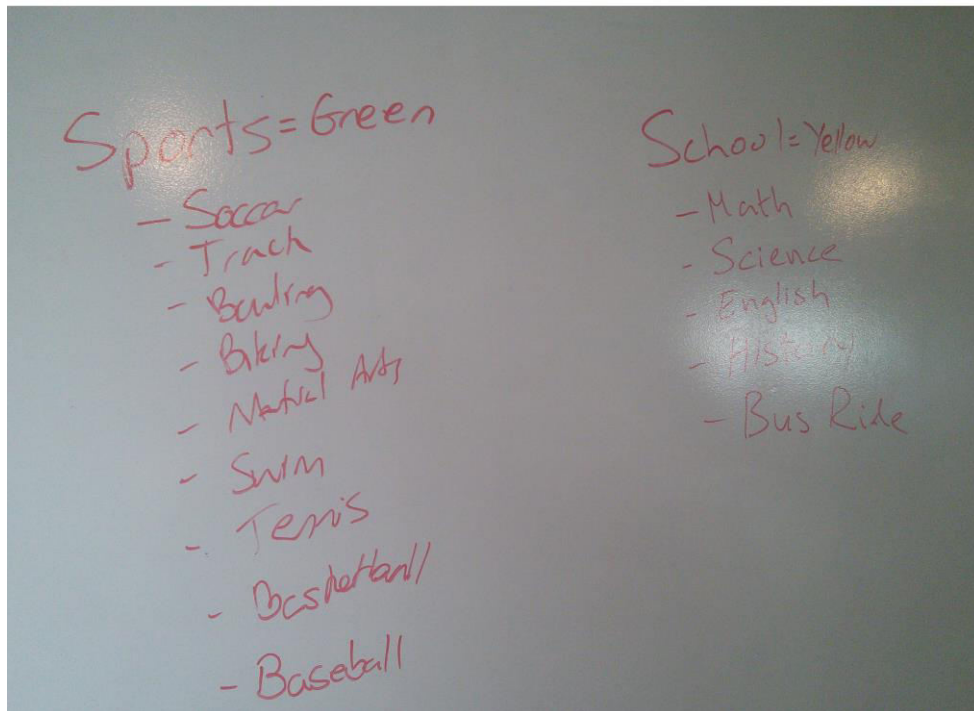
Figure 3.2 -1: Schedule Design Beginnings

3.2.1 Information Displayed

A scheduled event must have a lot of information associated with it, such as the name, category, and time. However, not all of the information can simply be displayed with words since it can be confusing for the child. To alleviate this, the application must show the required information in an appealing visual format. The visual aspect of the notification allows the child to be able to associate each event graphically. Looking at the examples of visual schedules for ASD, displaying the time and title in the form of a text along with an image and colored background signaling what the activity entails appears to be the best solution when displaying one notification at a time on a platform as small as a watch [7].

Figure 3.2.1 -1: Example of Visual Schedule

3.2.2 Colored Categories

A core aspect of visual schedules design is the background color, as it makes it easier for the child to create an association to an event category. The child needs to be able to not only know the event that he or she will be doing at the notified time but also the overall type of event. For example, a child is notified that math class starts soon. The notification will have a yellow background which is associated with the category for school events. Hopefully, the child will learn to categorize events based off of the background color, allowing for a quick association and less confusion when a new notification appears.

According to a journal article, children may be sensitive to certain colors which may lead to over-stimulation and cause a meltdown [3]. The app should not cause the child to have a meltdown simply because a color that is shown on the screen. Having too many stimulators causes havoc on the child's developing mind [26]. Also, studies have shown that children prefer muted or less intense colors over bolder ones [21]. Colors with minimal hues that have a calming effect are much more effective in assisting children with ASD. After researching articles about the colors and their effect on children with ASD, muted colors are to be used for assigning categories. The colors also need to be easily distinguished from one to another, so the child thinks of the category immediately without being confused or unsure.

There are five defined categories for the parent, physician, therapist or other authorized user to pick from when creating visual schedules: annual, appointment, daily, school and sports. Each color is assigned to a category for a specific reason, such as sports being green to represent a field and appointment being light blue to represent a doctor's appointment or speech therapy. Figure 3.2.2 -1 shows the color and the associated category.

Figure 3.2.2 -1: Color Category

3.2.3 Pictured Events

The other core component of the visual schedules is the picture that appears with an event. For example, under the daily category, there is a shower image representing a shower event. In this scenario, the parent can create a shower event on the schedule therefore sending out a notification with the shower image to the child through the VSA at the time of the event. The notification will trigger the visual association for the child and remind them to take a shower.

Children with ASD have an easier time thinking with visual images than with words. They have been found to excel with visual skills and perform poorly with verbal skills. For this reason, a child will associate a picture with an event much easier than if the actual word. For example, the words "over" and "under" means nothing until they're associated visually [13]. The word "shower" might mean nothing to a child, but the image of the shower will easily trigger an association with the shower event.

Autistic children are visual learners, and visual schedules play to their strengths [18]. First, they allow children to associate images with an event. When a shower picture is displayed, the child will remember the image and recall that it means time for a shower. With enough occurrences of the shower image, the child will be able to process this association automatically. Second, such associations should create less panic to any changes. No matter what, the child might develop repetitive behaviors and routines, some of which may be very difficult to change [19]. However, life isn't always predictable, and it is very difficult to stick to a strict routine. After enough repetition, the child will know what to do next when the shower image appears, even if it is not at the typically scheduled time. A child with ASD prefers predictability and routine [2], and the use of visual schedules helps in that aspect tremendously.

The visual events consist of graphically appealing and pleasing pictures for the child to use that can be easily associated with an event. For example, a soccer ball associates to soccer, while a calculator associates to math. The event image along with the background category should allow a child to have an easy association to an event. Figure 3.2.3 -1 is an example of the images connecting to events.

Figure 3.2.3 -1: Images for Events

Chapter 4

Application Development and Design

There are many components working together to get the visual schedules structure synchronized. These include the backend, the Autism Management Platform (AMP), scheduling website, iOS tablet, Google Glass, VSA and Android Wear. Each component offers a different contribution to the entirety of visual schedules, allowing each component to work for a specific group of users.

4.1 Backend

The backend has a lot of versatility making it easy to add new features. Data is stored in the backend and aggregated from various front-end systems with the use of Application Program Interface (API) methods. The versatility provided by using this protocol makes it easy for various types of front-end access ranging from Android to the web. The backend is explained further in David Tyler's thesis [27]. The figure 4.1 -1 shows how the front-end systems interact with the backend.
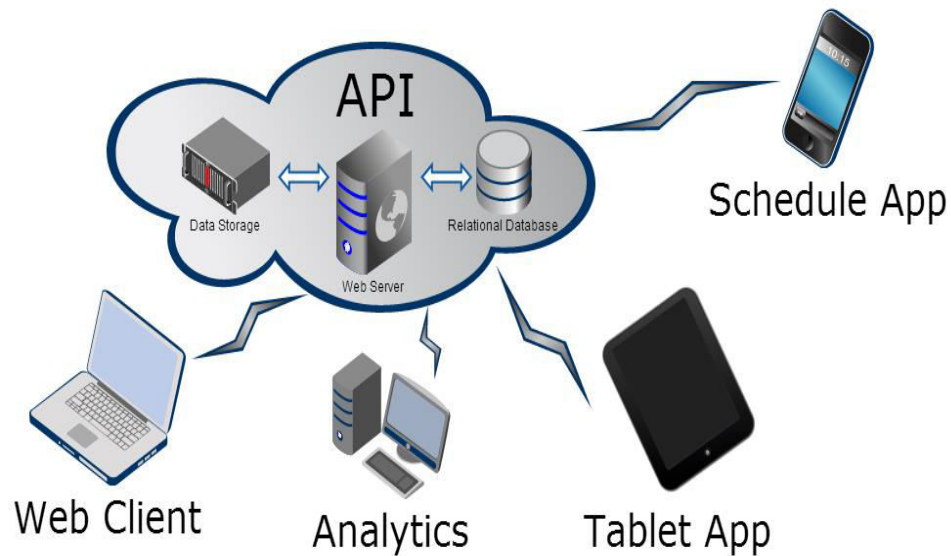
Figure 4.1 -1: Backend Architecture Diagram

4.2 Autism Management Platform

The Autism Management Platform (AMP) is a tablet application designed for the parents, family members and other authorized users to be able to view and track their Autistic children. It contains many features such as a tantrum timer, media input, main news feed for day-to-day activity, and medical feedback. Ryan Burns explains AMP and all of its available features in his thesis [9].

Figure 4.2 -1 shows a screenshot of the main news feed with many of the features available for the parent to use listed on the top row. This section is highly customizable and can support additional features without affecting the functionality of AMP.
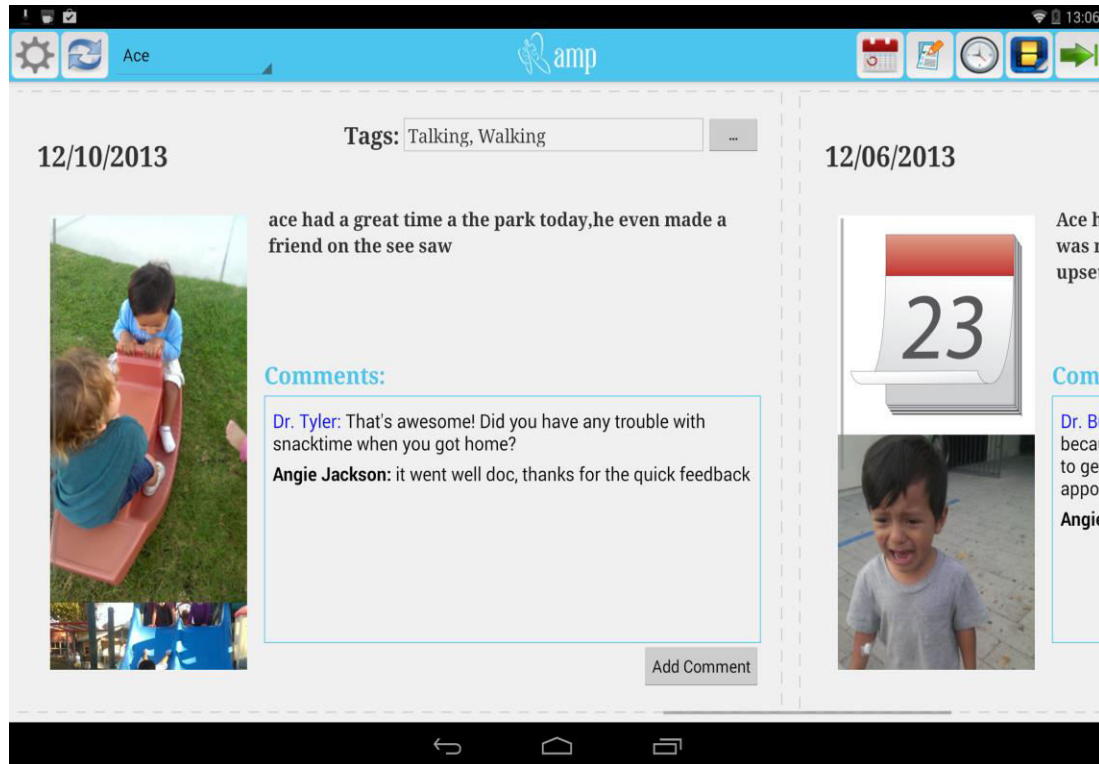
Figure 4.2 -1: AMP Main Feed

The visual schedule component of AMP is the first button on the right section of the top row, illustrated with the calendar image. The parent can use this feature to create or modify events for the child throughout each day. The events combine to create a schedule that helps to make the child's day easier. From the AMP tablet application, the parent can create different types of events, such as a weekly event or a daily event, and the time the event will occur. After selecting the type of event, the parent then selects the event the child will participate in, such as Science class, which will correspond to the image displayed to the child. Figure 4.2 -2 shows the events creation screen that the user will see after clicking on the events button from the main page.
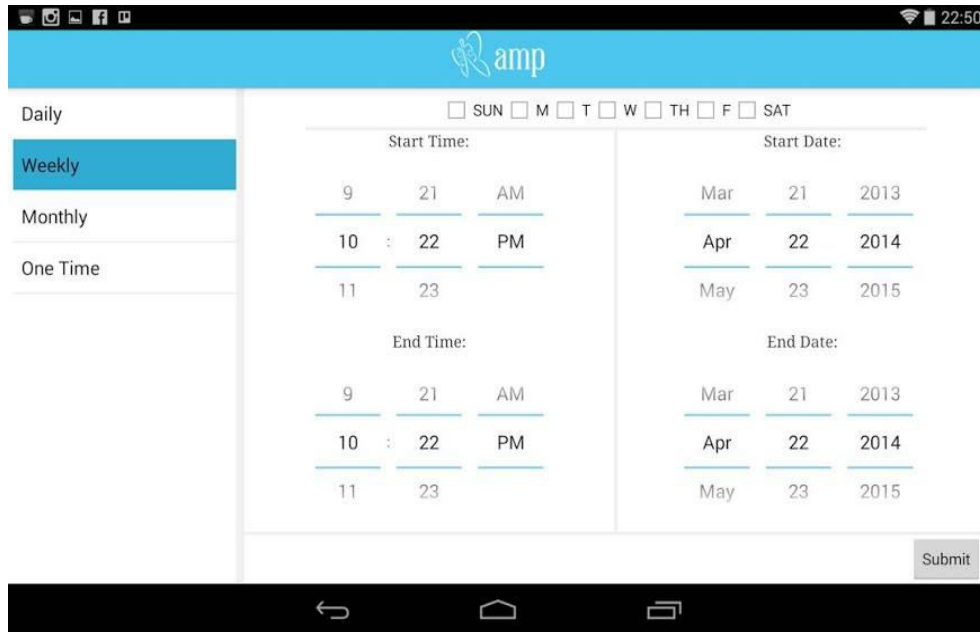
Figure 4.2 -2: Events creation screen

The objective is for AMP to allow for a parent, family member or other authorized user to have all information that pertains to their child with Autism. The ability to create and edit events from a tablet simplifies the process of maintaining a child's daily schedule.

4.3 Scheduling Website

Along with AMP, parents and other users have the option of using the scheduling website to create and view events for a child. The versatility provided by having a website makes it very easy for a schedule to be created and viewed. The left portion of Figure 4.3 -1 shows a menu containing all of their authorized children. On the right side of the figure, the schedule is displayed with the background color of the category and the title of the event.
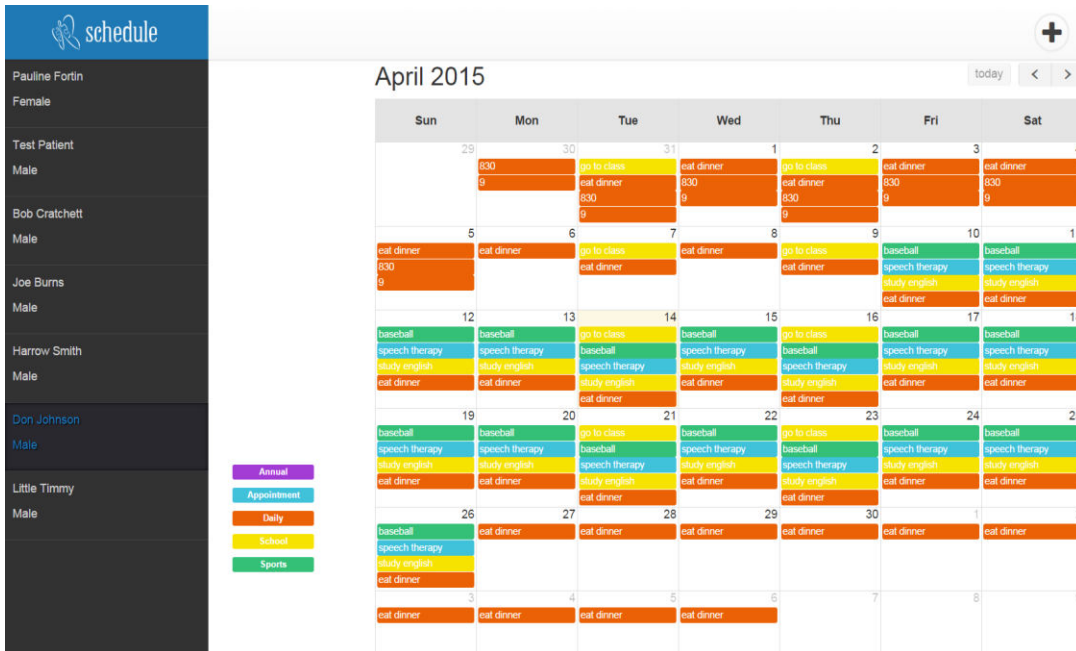
Figure 4.3 -1: Schedule Website

Along with viewing the schedule, the user can easily create an event by clicking

the plus button on the top right or edit an event by clicking directly on the icon. Figure

4.3 -2 shows the create screen.

Figure 4.3 -2: Website Event Creation

4.4 iOS Child Application

The child can use the iOS Application to view their schedule, which shows the next ten upcoming events. The application makes it easy to use as there is not much for the child to mess with that could cause confusion. An example of what the child sees through the iOS Application is shown in Figure 4.4 -1. It shows the event image, the background color corresponding to the category, date, start time and duration of the event.
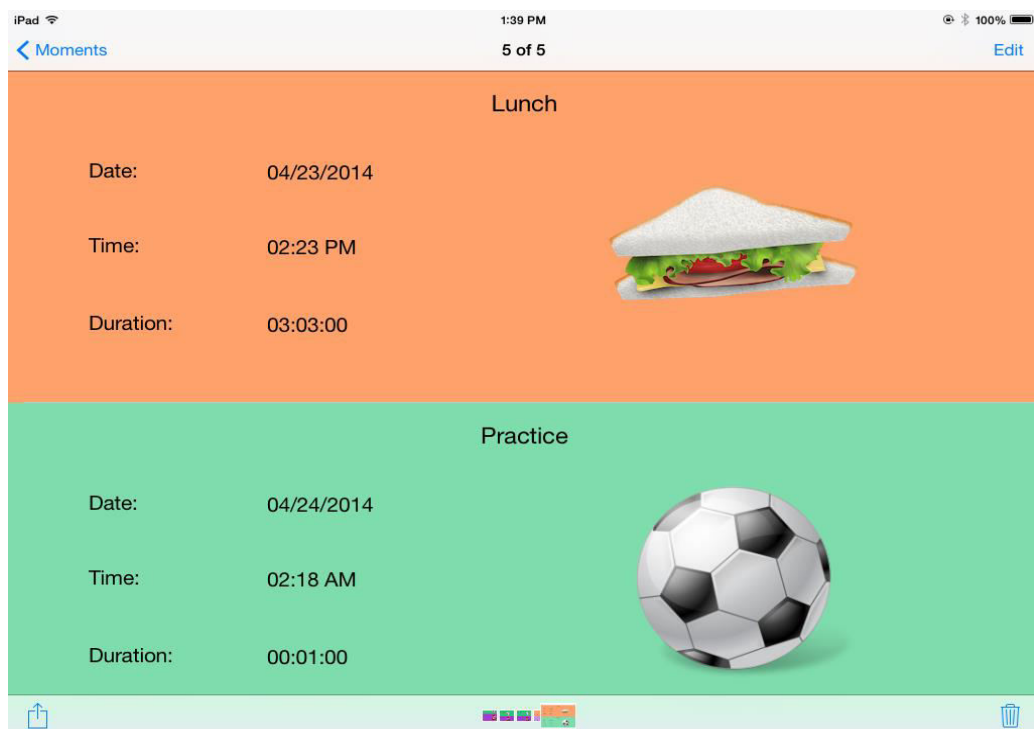
Figure 4.4 -1: iOS Schedule View

4.5 Visual Scheduling Application

The Visual Scheduling Application's (VSA) only purpose is for the child to use. This application works alongside AMP, the primary app for users such as the parent. The VSA is how the child will receive notifications and sees their visual schedules. Setup is done by the parent, and the VSA is made to be as childproof as possible.

4.5.1 Setup

After installing the application, the user is greeted with the login screen shown in Figure 4.5.1 -1. The sign-in process is similar to AMP or the website. Then the app will direct them to the Child Selection screen, illustrated in Figure 4.5.1 -2. The selection of a child ends the necessary setup section. The parent will no longer need to make any modifications on the app, except for when he or she needs to select another child. Every time the child opens up the application, they will be logged in and directed to viewing the schedule.
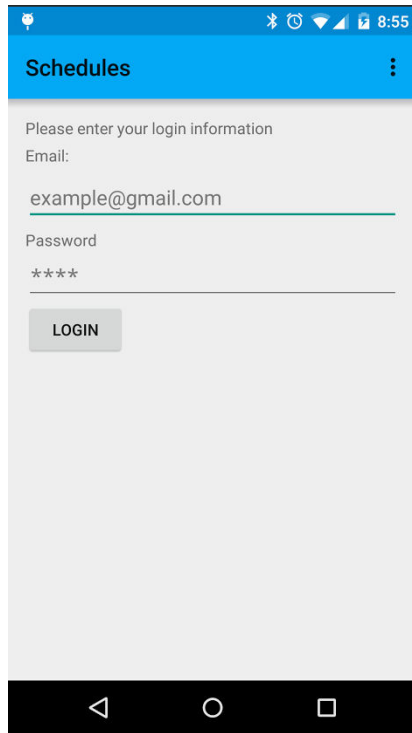
Figure 4.5.1 -1: Login Screen   Figure 4.5.1 -2: Child Selection
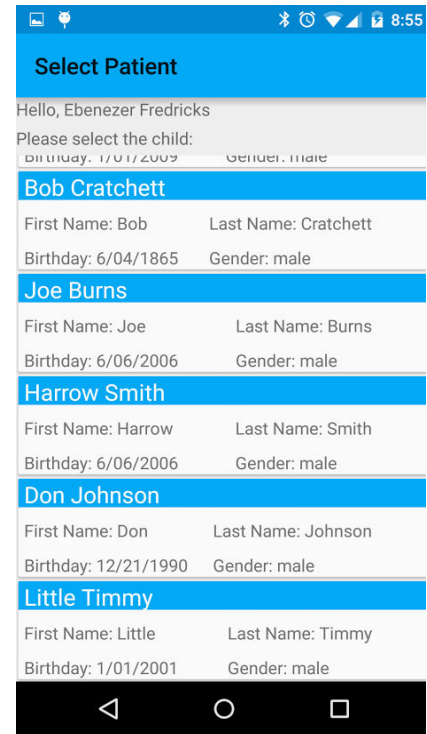
4.5.2 Viewing Schedule

After setup, the application will automatically go to a view showing the next ten scheduled events similar to the iOS application. The schedule will refresh upon opening, when the child swipes down, and when the refresh option is chosen on the menu. Simplicity is the key for the child to view his or her schedule, depicted in Figure 4.5.2 -1.
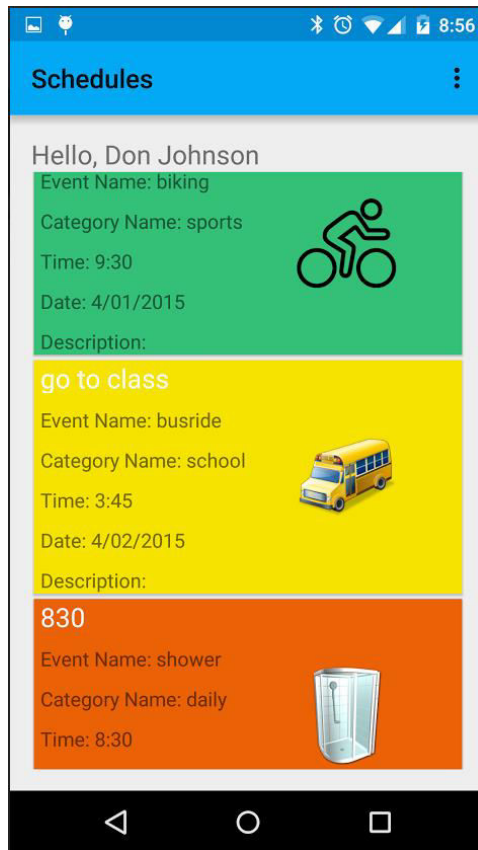
Figure 4.5.2 -1: Schedule View Tablet

4.5.3 Alarm Notifications

Every time the application is opened or refreshed, the alarms are reset which allows for easy synchronization. Additionally, the application will automatically create the alarms for the next ten events every time a notification appears. If internet access is unavailable, the application will automatically move on to the next scheduled event without checking for any newly added or modified events.

Once it is time for the event, a notification appears with the image and title of the event, as shown in figure 4.5.3 -1. The child can click on the notification or image to

open the app, and it will load the next ten events. Clicking on the notification is similar to

the child opening the app through the icon.
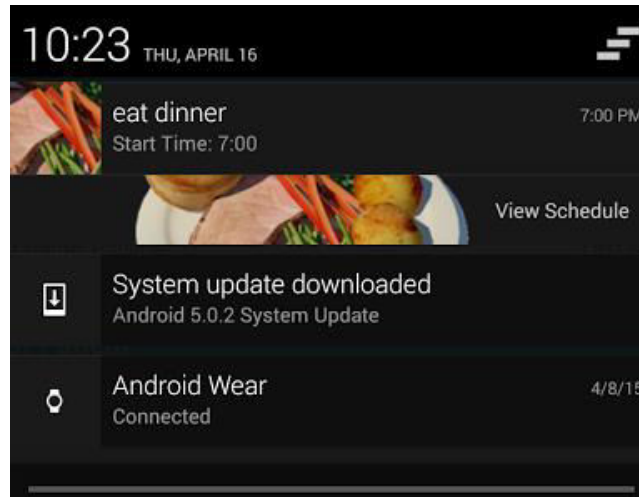
Figure 4.5.3 -1: Alarm Notification Tablet

4.5.4 Application Design

Since this application has the child in mind, decisions were made reduce as much

confusion as possible. One example is that the application can not rotate. With the screen

rotation locked, the child knows exactly which way the application will open every single

time. Next, the menu system only has options to set, cancel, and reset alarms as displayed

in figure 4.5.4 -1. Ultimately, the child can only modify if the alarm notifications will or

will not occur. He or she does not have the option to change, cancel or add events. The

child does not even have the option to select which events have a notification and which

do not, creating much-needed simplicity.
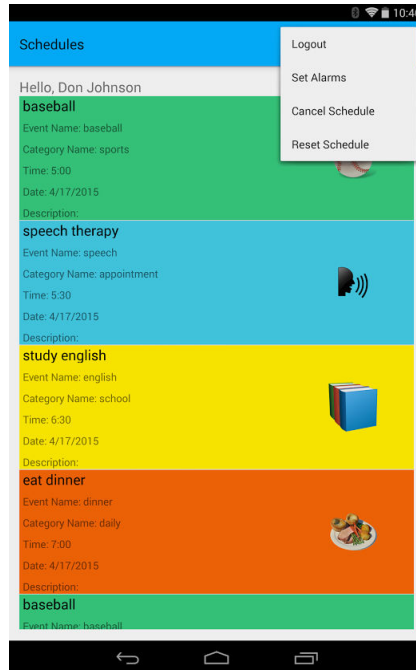
Figure 4.5.4 -1: Schedule with Menu

Another concern is when the parent wants to use the application for another child. It does not make a lot of sense to set up the application without the ability to be changed. In the menu, the user has the option to log out. However, the user must enter the correct password first. Therefore, the child can't accidentally set up his or her schedule for another child user.

Forcing the password to log out, shown in Figure 4.5.4 -2, helps prevent the child from making an accidental logout. More importantly, it prevents the child from setting and receiving alarms for events that belong to somebody else. If the child gets notified about another person's schedule, the events could be drastically different from what they are used to and may increase the amount of anxiety faced through their day.
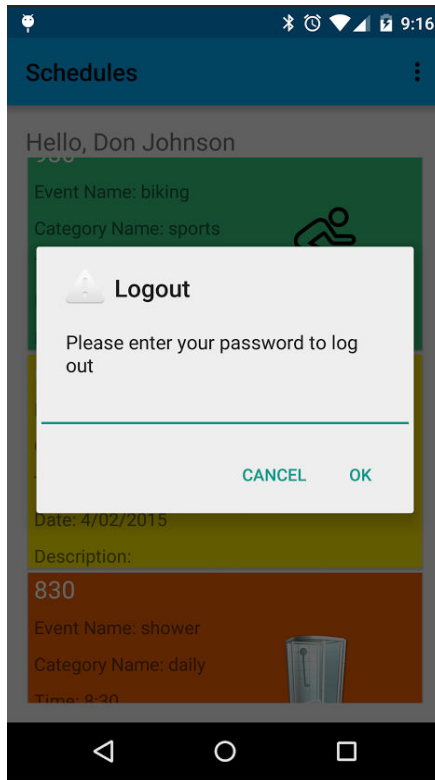
Figure 4.5.4 -2: Logout screen

Another issue that could occur is going back to the pick a child screen. The back

button is always there and by default goes back to the previous screen. To prevent the

child from going back to the pick a child screen, the only function of the back button is to

exit the app. The back button override minimizes the chances of accidental changes, as

the only way to change children is by logging out and entering the password verification.
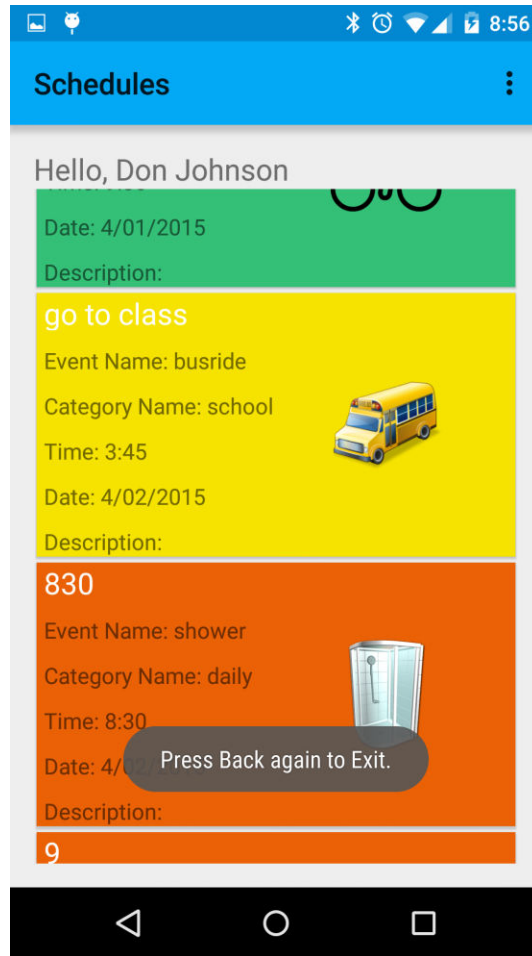
Figure 4.5.4 -3: Exit Verification

4.5.5 Wearable Technology

Wearable technology allows everyday life to be integrated with technology. Simply looking down at a watch or looking up through the corner of a pair of glasses provides minimal obtrusion while going through daily life activities. A user can continue interacting with the environment, and a notification will simply appear through the technology. The user will notice the notification and can choose to ignore it or respond with ease. This idea makes it a solution for an Autistic child to use since the child does

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not have to rely on a phone or website for an update. New technology like Google Glass

and Android Wear are great examples of how wearable technology can help a child.

4.5.5.1 Google Glass

Google Glass was one of the first pieces of wearable technology invented. The

glasses are worn similar to a regular pair of glasses that the user wears all the time. The

difference between Google Glass and regular glasses is a small display on the upper

right-hand corner, which shows relevant information to the user. With visual schedules,

the notification will show onto the display when an event occurs, and the child can get rid

the notification by simply swiping down on Google Glass. Figure 4.5.5.1 -1 displays the

Google Glass point of view for a child when a notification appears.
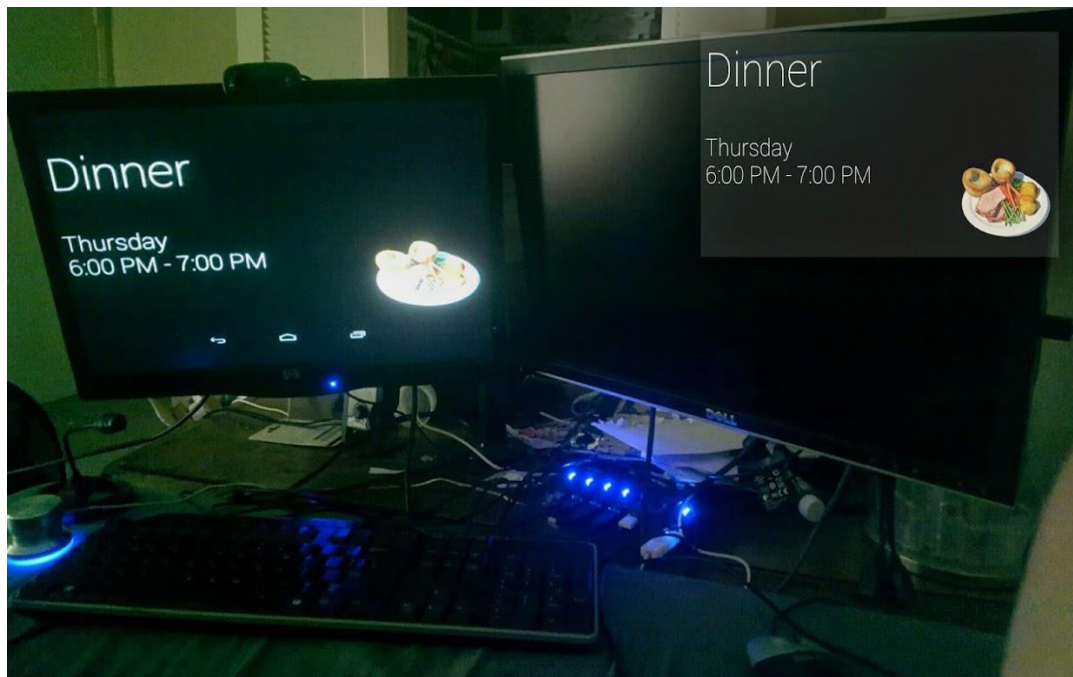
Figure 4.5.5.1 -1: View from Google Glass
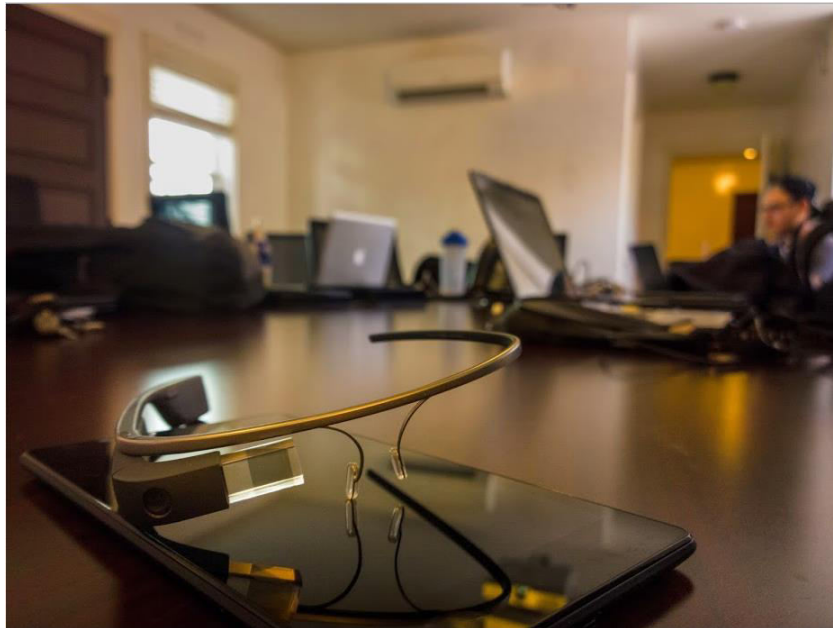
Figure 4.5.5.1 -2: Google Glass

4.5.5.2 Android Wear

While wearing Google Glass looks cool, it's unrealistic for the child to be running around with an expensive piece of technology. Android Wear provides a relatively cheap and durable alternative for users, with a collection of watches that can work together with an Android phone or tablet using Bluetooth. When it comes to the VSA, the notification that appears from the application will also appear on the watch display. For example, a child is sitting on the floor playing with his or her toys when a notification, along with a noise or vibration, appears on the watch signaling that it is time for dinner. The child looks down and recognizes it is time for dinner since the notification looks familiar, and the child visually associates the event image with going to eat.
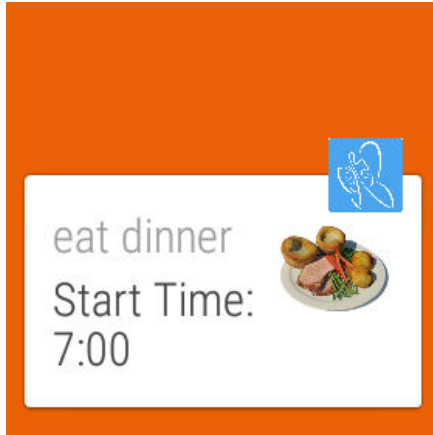
Figure 4.5.5.2 -1: Watch Notification
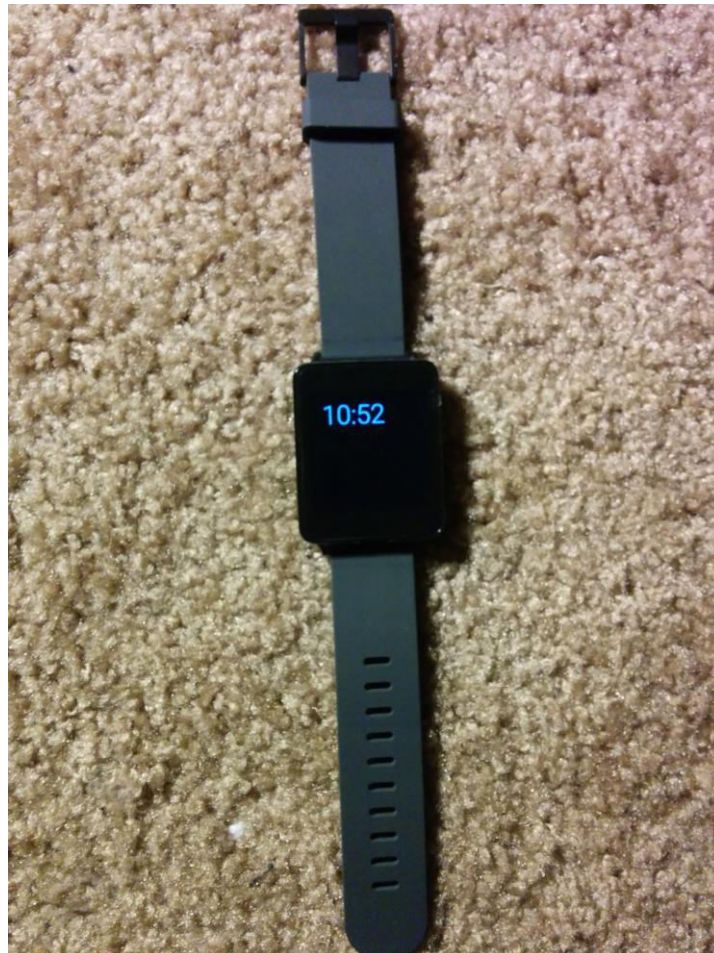
Figure 4.5.5.2 -2: Android Wear

Chapter 5

User Experimental Testing

After the development of the VSA, user review was necessary to assess how useful and practical the application with Android Wear could be in the lives of children diagnosed with ASD. Applied Behavior Analysis (ABA) Therapist, Ria Tirona reviewed the application and compared it with her work in the field, comparing visual schedules with those she had used over the past four years.

5.1 User Interface Review

The application demonstrated just how powerful wearable technology can become in helping the development of children with Autism. The visual representation of the event was nice and very easy to understand. The notification aspect of the visual schedules allows the child to know when an event occurs, and the watch vibration to alert the child is great. However, the usability of the watch is a concern. The use of a watch is a new concept that many people are not used to. A child may not know how to dismiss a notification on the watch, but any new notification that appears will override the previous one allowing for less confusion.

An appreciated aspect of the application in the review is the childproofing, which provides parents with an ease of mind. The inability to change children or accidently set up a schedule for someone else without the parent's permission drastically decreases the

likelihood of scheduling errors. Childproofing was done to help create as little confusion and undesired edits as possible, and the review showed how useful the implementation was.

5.2 Concerns

After reviewing the application and comparing it with visual schedules in the past, many concerns came up. One of them is the fact that not every parent can afford the cost of owning a smartphone and a smartwatch. There isn't much that can be done to help alleviate this problem other than hoping that the prices will come down.

Another problem is the requirement of always having an Android device available to pair with the watch, whether it is a tablet or phone. A parent might necessarily trust their children to carry both a smartphone and a smartwatch with them all the time. However, Android is now creating technology such that the watch will work without being paired to a tablet or watch provided that there is Wi-Fi available [20].

Another concern for the application is that the child might not be able to recognize the title as many children have developmental delays. The idea of the image such as a soccer ball to go with soccer practice provides a great visual cue to go with it, but custom images would be a great improvement. Since each event can have a title and category, the ability for a parent or therapist to choose a personal image might be the most effective way for the child to create visual cues. The plan in the future is to be able to upload a custom image along with each event.

Chapter 6

Data Collection

When a notification appears, a child can have a reaction ranging from calm to very hectic. The application is set to collect data before, during and after the notification to detect if significant changes occur due to schedule changes. The data can be used to detect if certain notifications cause bad reactions such as a temper tantrum.

6.1 Heart Rate

With the new feature of heart rate monitoring, the watch can be used to determine the heart rate around the time of the notification. With sufficient data collection, it can be determined if the child has a major reaction to the notification or no major change at all. In Figure 6.1 -1 below, the heart rate graph shows if the child has a mild or major reaction to the changing of schedule. The graph illustrates that the child's heart rate went up, signifying that he or she had a reaction at the time of the notification. Heart rate is an important piece of data to collect, as this can be a sign of anxiety and panic occurring.
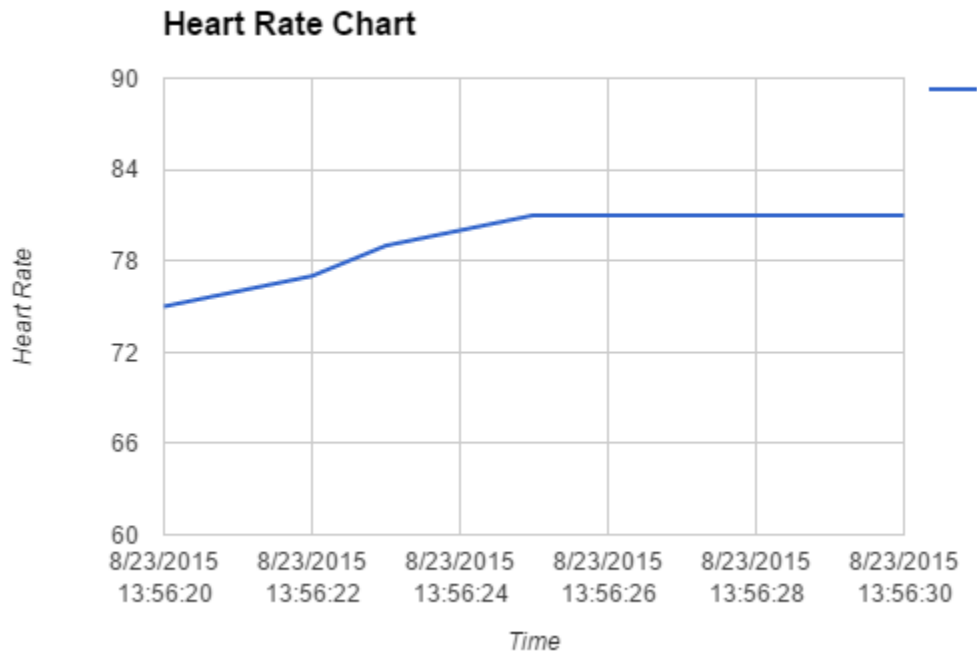
Heart Rate Chart

Figure 6.1 -1: Heart Rate Chart

6.2 Location

The location feature allows for the collection of the child's position. The application will get the child's longitude and latitude so that the rate of change and position can be determined. If the rate of change increases after the notification, this signals that the child is moving quickly and might be experiencing a panic attack. On the other hand, if the rate of movement remains the same, then this signals the notification did not have any effect on the child's velocity.
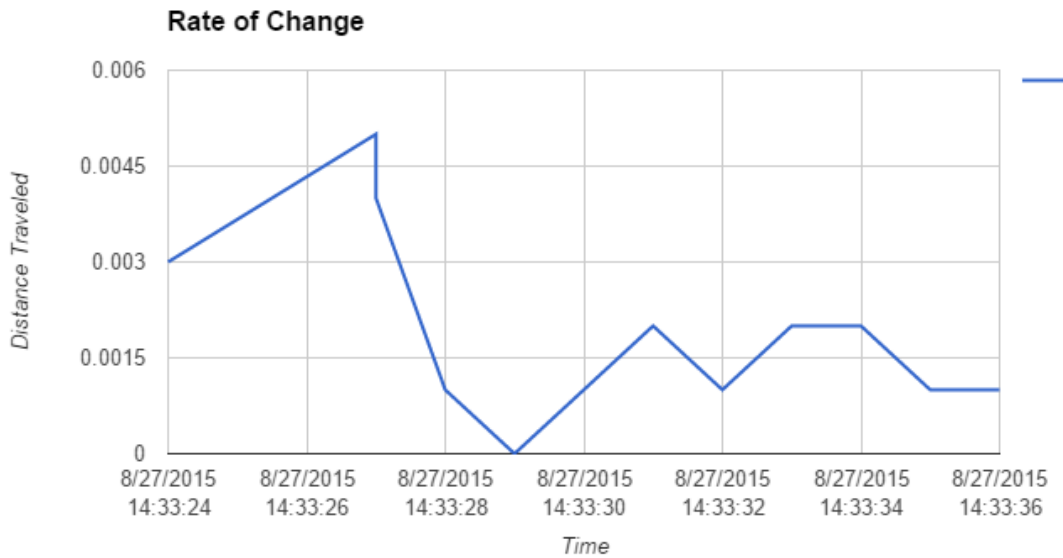
Figure 6.2 -1: Location Chart

The graph above of the child's rate of change shows no major rate of change from visual schedules notification. While there is a pretty big change at 14:33:27, the rate of change is still less than one mile, meaning the child likely did not have a panic attack and end up running around.

6.3 Audio Recording

The application will also record the noise before, during and after the notification. Audio recording allows for detection of noise levels and if the child is having a tantrum. For example, if the noise level is low before the notification, but very high after the notification, a tantrum has occurred.

As seen from Figure 6.3 -1, the audio is low in the beginning but gets higher as the time goes on. The audio levels show a change in volume occurs at the 6-second mark, meaning the child might have had a significant reaction to the notification.
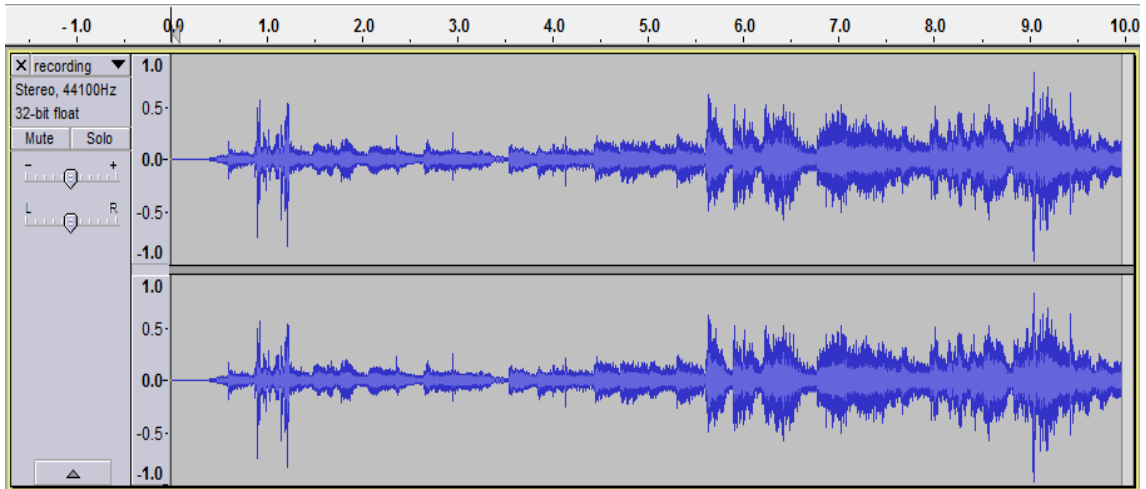
Figure 6.3 -1: Audio Chart

Chapter 7

App Store Data Mining

Along with creating the VSA, data is collected on apps and reviews about Autism for analysis. The data can help determine what kinds of apps are available to help children with Autism. The data will also show each app's pros and cons along with any complaints a user may have.

7.1 Gathering the App Information

Before analysis, information and reviews must be collected for each app. Apple has a built-in iOS API that makes it simple to find the apps based off of a search term. For Google Play, there is no built-in API, but 42matters [1] has an API that makes it possible to gather information about Autism apps on the Google Play Store. A search was conducted for all apps that appear under the search term "Autism", and all the relevant data was loaded into a CSV for later use.

```
{
  "screenshotUrls":[ 00 ],
  "ipadScreenshotUrls":[ 00 ],
  "appletvScreenshotUrls":[ 00 ],
  "artworkUrl60":"http://is4.mzstatic.com/image/thumb/Purple69/v4/5b/33/63/5b3363d0-2d09-45a6-8c8b-4426af1c081d/source/60x60bb.jpg",
  "artworkUrl512":"http://is4.mzstatic.com/image/thumb/Purple69/v4/5b/33/63/5b3363d0-2d09-45a6-8c8b-4426af1c081d/source/512x512bb.jpg",
  "artworkUrl100":"http://is4.mzstatic.com/image/thumb/Purple69/v4/5b/33/63/5b3363d0-2d09-45a6-8c8b-4426af1c081d/source/100x100bb.jpg",
  "artistViewUrl":"https://itunes.apple.com/us/developer/duke-health/id906753232?uo=4",
  "kind":"software",
  "features":[ 00 ],
  "supportedDevices":[ 00 ],
  "advisories":[ 0
    "Infrequent/Mild Medical/Treatment Information"
  ],
  "isGameCenterEnabled":false,
  "trackCensoredName":"Autism & Beyond",
  "languageCodesISO2A":[ 0
    "EN"
  ],
  "fileSizeBytes":"86907413",
  "sellerUrl":"http://autismandbeyond.researchkit.duke.edu/",
  "contentAdvisoryRating":"12+",
  "userRatingCountForCurrentVersion":1,
  "trackViewUrl":"https://itunes.apple.com/us/app/autism-beyond/id1025327516?mt=8&uo=4",
  "trackContentRating":"12+",
  "averageUserRatingForCurrentVersion":5.0,
  "formattedPrice":"Free",
  "currency":"USD",
  "wrapperType":"software",
  "version":"1.0.2",
  "description":"Autism & Beyond is a groundbreaking new study of childhood mental health powered by Apple's ResearchKit. The study aims to test new video technology that can analyze a child's emotion and behavior. We hope th
\t Learn about all children and families\n* \tCreate new screening tools for autism and challenging behaviors and emotions, like tantrums and anxiety\n*\t Support children's healthy development\n*
\t Gain a better understanding of what parents need\n\nEligibility:\nYou and your child are eligible to participate in the Autism & Beyond study if:\n*\t You are at least 18 years of age\n*
\t You have a child who is at least one year old or less than 6 years old\n*\t You are the parent or legal guardian of this child\n*\t You are able to read English\n*
\t You live in the United States\n\nNote: When you join the study you will have the option to send video recordings to Duke to help us improve our technology, or you may choose to send just a data file with no video recordings. Main
  "artistId":906753232,
  "artistName":"Duke Health",
  "genres":[ 0
    "Medical",
    "Health & Fitness"
  ],
  "price":0.00,
  "trackName":"Autism & Beyond",
  "trackId":1025327516,
  "bundleId":"org.dukemedicine.OurChild",
  "releaseDate":"2015-10-15T05:59:42Z",
  "primaryGenreName":"Medical",
```

Figure 7.1-1: iOS JSON Result

ID	Developer	Name	TotalRati	CurrentR	TotalNum	CurrentN	Currency	Price	Formatte	Market
1025327516	Duke Health	Autism & Beyond	4	5	5	1	USD	0	Free	iOS
441600681	Touch Autism	Autism Apps	3.5	4	242	4	USD	0	Free	iOS
557548372	John Talavera	Autism iHelp â€" WH Questions	3.5	3	81	11	USD	0	Free	iOS
303153532	Toddler Teasers	Shapes Toddler Preschool	3.5	3.5	18137	220	USD	0	Free	iOS
521485216	John Talavera	Autism iHelp â€" Play	4	4	62	23	USD	0	Free	iOS
612955883	Cubic Frog Apps	Preschool EduKidsRoom- Free Educational Games For Toddlers & Kindergarten Kids!	4.5	4	14977	126	USD	0	Free	iOS
588180598	Touch Autism	Social Stories Creator and Library for Preschool Autism and Special Needs	4	3	83	2	USD	0	Free	iOS
312571156	Learning Touch LLC	First Words Sampler	4	4	17197	309	USD	0	Free	iOS
444722625	77Sparx Studio Inc.	Toddler Kids Puzzles Puzzingo â€" Educational Learning Games	4.5	5	3532	1	USD	0	Free	iOS
478527813	Track & Share Apps LLC	Autism Tracker Lite: Track analyze and share ASD daily	4.5	4.5	80	7	USD	0	Free	iOS
550027186	Model Me Kids LLC	Autism Emotion	4	4	25	25	USD	0	Free	iOS
598935321	John Talavera	Autism iHelp â€" Language Concepts	4	3	17	6	USD	0	Free	iOS
587107345	Cubic Frog Apps	Preschool EduKitchen - Free Early Learning Educational Kitchen Cooking Games For Toddlers!	4.5	4.5	6656	90	USD	0	Free	iOS
609622929	John Talavera	Autism iHelp â€" Sorting	3.5	3.5	22	13	USD	0	Free	iOS
491925436	Tigerface Games	FindMe(Autism)	3	3	91	12	USD	0	Free	iOS
592995014	John Talavera	Autism iHelp â€" Colors	3.5	2.5	15	4	USD	0	Free	iOS
331399332	Cold Spring Harbor Laboratory	3D Brain	3.5	4.5	9941	8	USD	0	Free	iOS

Figure 7.1-2: Apps CSV

7.2 Gathering the App Reviews for Analysis

After information collection on the apps, reviews were gathered for each of the individual apps for data analysis. Information included the title, rating, and review of each app. The title and review information were parsed into an individual file, so the data was ready for analysis.

```
Good resource
I have had this app for a while and I have to say it has gotten
better and better.  It was sluggish in the past  but I find it
working much better and I have found some great apps on it.
Great job. Thanks!!!
```

Figure 7.2-1: Parsed File

7.3 Topic Modeling

Topic modeling is a form of text mining or a way of identifying patterns in a corpus [8]. In other words, it makes it possible us to take documents with a seemingly random number of words and organize them such that each document contains topics with clusters of words. The categorization allows the documents that seem to have no correlation to one another to be organized in a way that shows what they have common with one another.

Latent Dirichlet Allocation (LDA) is used for our data analysis. LDA represents a mixture of topics that spit out words with certain probabilities and creates topics based off of the documents provided. Each word associates with a topic randomly in the beginning and then ran again and again until a topic stabilizes. Then each document is given a proportion to the topics. For example, a document consists 70% of topic 1 and 30% of topic 2.

7.4 Data Analysis

For analysis, Topic Modeling with Mallet is used. Topic modeling allows for organization and analysis of large volumes of unlabeled text, and a topic consists of a cluster of words that frequent together [23]. Mallet comes in a tool with an input directory to select the parsed files. Then Mallet outputs files such as the topics with words and how much each topic would pertain to each file.

When Mallet produces the files, a general idea of what each of the topics pertains to can be determined. For example in Figure 7.3-1, topic 3 promotes the idea that the apps about that topic are used to help a child better understand colors and shapes. Topic 8 pertains to words used if an app is not great or working well since it contains the words doesn't, work, back and money together.

topicId	words..
1	app nice students love people works program favorite track enjoy
2	child easy autism tool simple pictures helpful speech language option
3	app great children learn wonderful shapes found colors years learned
4	loves year great son learning daughter words letters playing month
5	app version free full fix buy working read loved year
6	app apps recommend worth toddler paid time you've find data
7	game make love awesome games amazing school toca things cool
8	app work time don't sound ipad doesn't cute back money
9	kids good fun great love educational videos sounds puzzles perfect
10	play love add update baby lot parents home store ads

Figure 7.3-1: Topics and Words

Mallet also produces a file that shows how much each file pertains to each topic. Since there a general idea of what each topic is about, there is a general idea about each review. For example, in the review of the Autism iHelp – WH Questions 33% of the review pertains to Topic 5, 27% pertains to topic 6, 20% pertains to Topic 8 and 20% pertains to Topic 7. Topic 5 has the most words associated and the words include app, version, free, full, fix, buy, working, read, loved, year. The assumption is that the app does not work properly. Topic 8, the third most pertinent topic, contains the words doesn't, work, back, and money. After looking at the actual reviews on the app, the assumption is correct, as most reviews discuss how bad the app is. Displaying the percentages of topics contributing to a review with a pie chart makes it easier to understand.
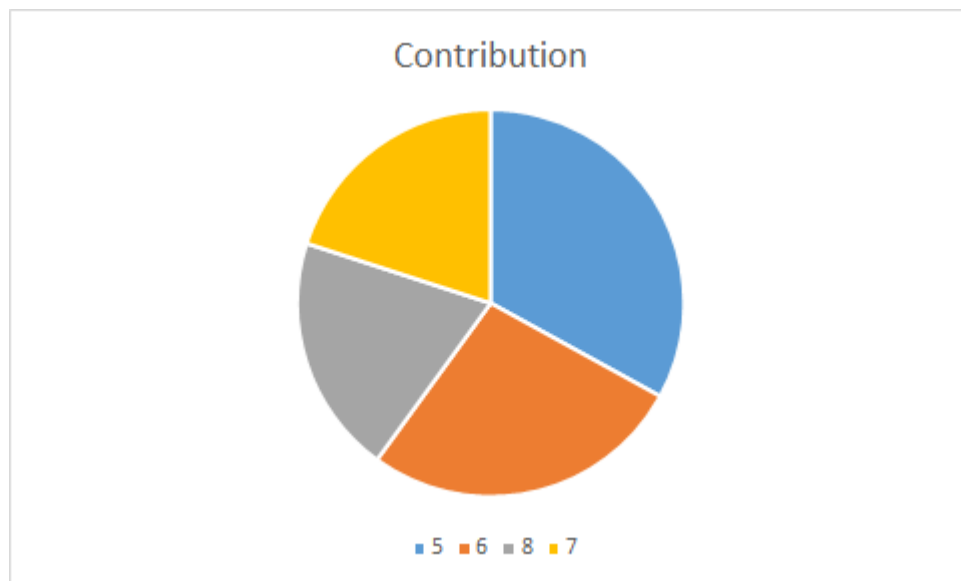

Figure 7.3-2: Topic Review Pie Chart

7.5 App Analysis

The data is used to help conduct analysis on the apps pertaining to Autism. Specifically, the price and rating were used for analysis. The price and ratings help to determine if an app is worth buying and how helpful each app is.

7.5.1 Price Analysis

The apps for Autism available for iOS and Android are mostly free. Of the ones that required payment, only two had costs above $10 with the Proloquo2Go - Symbol-based AAC app costing significantly more than the rest at $250. Figure 7.5-1 shows that there are much more free apps than paid ones, with very few costing over $5. Free apps are much more widely available since people are much more likely to try an app that has no financial ramifications. Additionally, a user is much less likely to use an app that requires payment if a free app with similar functions is available.
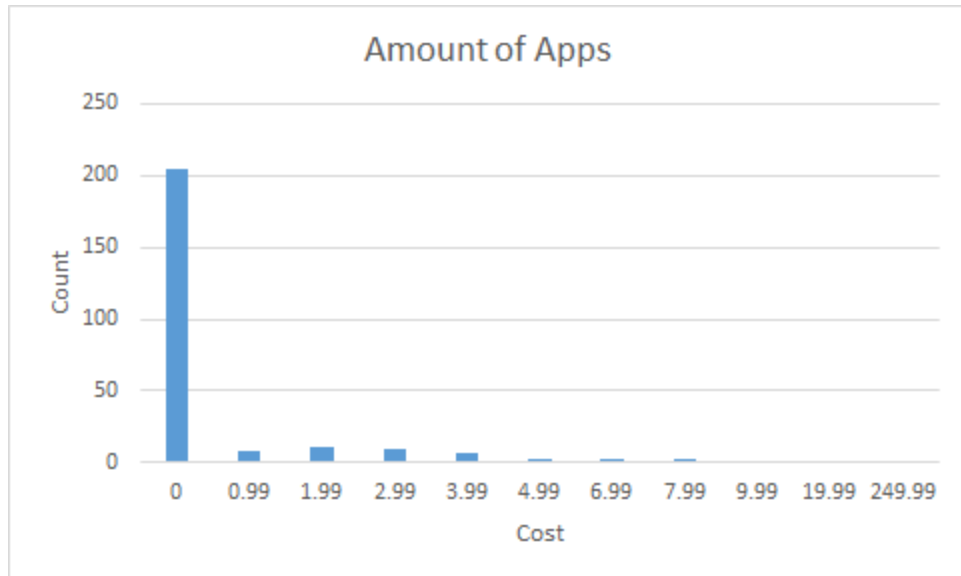
Figure 7.5.1-1 Cost of Apps

7.5.2 Price vs. Rating

Ratings are a good way of determining the how useful and functional an app is. For example, a person first downloads an app thinking it will useful. Then if the app is full of problems, they would leave a low rating review. Figure 7.5.2-1 shows that in general, average app rating goes up as the price goes up. Figure 7.5.2-2 shows that the amount of reviews for free apps far outnumbers the amount of reviews for paid apps. The results show that while a majority of apps are free, there is a higher number of bad reviews for free apps. Since the apps are free, more people are willing to take a chance. With apps that cost more money, people are doing research first and only selecting those that appear favorable.

Studies have shown that people are far more likely to share a bad experience than a good experience [5] Therefore, people are more likely to write a review if there's a bad experience with an app, but people will not leave a review if they have a neutral or good experience. This means that a higher number of bad reviews and a lower rating means the product causes a lot of negative experiences.
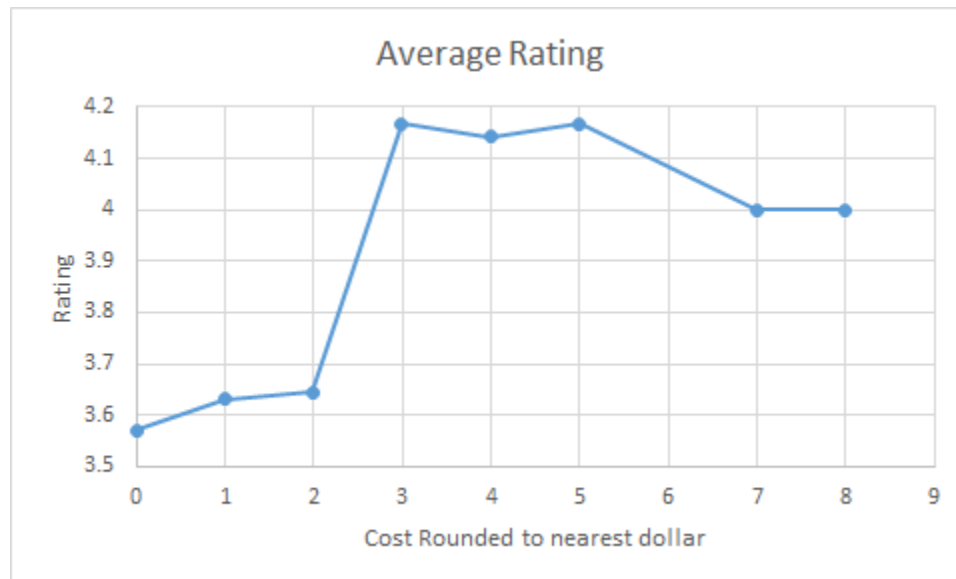
Figure 7.5.2-1: Average Rating by Price

Price	Total Reviews	Average Rating
0	316426	3.57
0.99	2303	3.63
1.99	5396	3.644834692
2.99	8224	4.166666667
3.99	4505	4.142857143
4.99	1496	4.166666667
6.99	20	4
7.99	1020	4

Figure 7.5.2-2: Average Rating and Total Reviews by Price

Chapter 8

Future Potential

Visual Schedules is just the beginning of how technology can help ASD. Smart watches show the benefits of wearable technology, and there are much more possibilities for the watch. With a versatile backend and many other incorporated applications, the VSA has a lot of potential to help children with ASD.

One goal of the application and the watch is to add more features. For example, an additional feature would be to incorporate direct picture messaging. Similar to the visual schedule notification, the child would be able to get an image message from the parent with a visual cue.

Wearable technology is in the infancy of its creation. The introduction of glass and watches begins a whole new branch of technology, even less intrusive on everyday life than a cell phone. Apple announced Apple Watch as their answer to Android Wear. Apple Watch can incorporate as a part of the iOS application, similar to Android Wear on the VSA. Since the entire system and backend allow for easy integration, adding features to the iOS application would not ruin the system.

Children diagnosed with ASD have many things going on in their lives and research has only begun to show how advancements in technology can help. Visual Schedules and wearable technology add to this by making the daily lives of these children

even simpler. Visual schedules play to the children's strength of being visual learners, and wearable technology allows for unobtrusive and easy cooperation with the child's life. With further research and development, there are endless opportunities for improving and enhancing the lives of those affected by ASD.

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