A Mobile Platform for Teaching Nonverbal Social Communication Skills to High-Functioning Autistic Children Using Discrete Trial Training

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Abstract

The purpose of this project is to provide a mobile platform for teaching nonverbal social communication skills to high-functioning autistic children. The application uses the established method of Discrete Trial Training to deliver customizable programs that can be tailored to meet the unique needs of children with autism. Although the focus of this study is nonverbal social communication skills related to gestures, the mobile app (designated "Wave") enables the teaching of a wide array of basic skills, including attention, perception, reasoning, memory, reading and writing, and motor skills, through matching exercises, imitation exercises, and natural environment training. Wave allows programs to be customized and enables adjustments to be made to fit the specific educational needs of an ASD (autism spectrum disorder) child. Its portability supports learning at any time and in any location, allowing users to take the classroom experience with them and to transfer the learning process to natural environment settings, including family settings and public environments. Furthermore, it helps teachers to save time by allowing them to reuse programs and decreases their workload by offering easy access to monitoring children's data.

For this project, two versions of an initial interactive prototype (one for iPhone and one for iPad) were created using Axure in order to test the mobile delivery method. Four user tests were conducted with these versions to identify the user requirements for designing the application. Findings from these tests were used in developing the second prototype application, which was built using jQuery Mobile. Two pilot tests and twelve user tests, with participants who included Discrete Trial Training experts, were conducted using the app on an iPad. These user tests resulted in overall improvements of the application to enable it to support the needs of educators, parents, and autistic children.

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Chapter 1: Introduction

Autism spectrum disorders (ASD) encompass a continuous spectrum of communication deficits, social impairments, repetitive behaviors, and restricted interests. People with autism may also show abnormal responses to sensory stimulation such as sound, light, or smell. Autism begins early in childhood and generally affects the daily functioning of the autistic person throughout his or her lifetime. The extent of the impairments and the nature of the behaviors that result from ASD vary considerably among those who have ASD, depending on their developmental level and degree of disability.

In order to achieve positive progress, autistic children require a customized training program that matches their specific developmental levels, communication capabilities, social abilities, and motor skills. Among the various tools for educating children with ASD, the use of computer applications stands out, due to their capacity for customization. A successful app for educating children with ASD should allow for the customization of training requirements according to each child's individual characteristics.

According to Fernández-López et al. (2013), the educator should consider two dimensions in customizing a training program: the user dimension and the learning dimension. The user dimension for teaching high-functioning children with autism consists of identifying each child's particular capabilities and limitations related to communication, social skills, sensory issues, and cognitive impairments. This will provide a user profile that allows the educator to determine which training adaptations are necessary for each specific ASD child.

The learning dimension consists of designing activities that cover a set of learning objectives, including social skills, communication, attention, perception, cause-effect relationships, interpretation, semantics, and pragmatics. In order to achieve these learning objectives, the first step is to analyze how the training program should be defined for the specific educational needs of an ASD child. Educators must then define a training plan consisting of personalized activities. These activities should be sufficiently flexible to adapt to the characteristics of each child (Fernández-López et al., 2013).

Studies on the behavior of autistic children show that autistic children favor predictable situations, which are less stressful for them to comprehend (Dratsch et al., 2012). Since people's behavior can be subtle and unpredictable, autism therapies mainly focus on using reliable settings with controlled complexity. The majority of these therapies use various objects, such as toys and pictures, to teach different concepts and to conduct interventions. Computer-assisted interventions can be used in this regard to provide a simplified, safe, predictable, and reliable environment where the complexity of the interaction can be controlled (Robins & Dautenhahn, 2004).

There are several therapy methods available that focus on improving the core deficits in ASD. Discrete Trial Training (DTT) is an instructional approach used to teach skills in small, repeated steps. In this method, each step is a discrete trial with a definite beginning and end, and desired behaviors are reinforced by positive praise or tangible rewards. Users' progress, challenges, and skill acquisitions are monitored and recorded for planning and adjustment of the training program. In the Discrete Trial Training approach, a single response to an instruction is called a trial. Each trial consists of the following five steps:

1. **Stimulus:** *Stimulus* or *antecedent* is the trainer's instruction. The stimulus is the first part of the discrete trial and it instructs the child about the task in hand.
2. **Prompting:** *Prompting* refers to indicating the correct response to the child. Prompts are supplemental teaching aids that would be reduced based on set criteria. After a prompt has been used a number of times and the child responds correctly at a certain frequency, the prompt might then be faded out to a partial gestural prompt and eventually faded out further so that no prompting is being used.
3. **Response:** The response, also called *target behavior* or *behavior*, is the child's response to the instruction and comes after both the stimulus and the prompt.
4. **Consequence:** Based on the response, the trainer gives immediate feedback to the child. If the response is correct, positive reinforcement is provided in the form of verbal praise (such as "good job") or delivery of tangible reinforcement (such as sweets). If the response is incorrect, the trainer uses a prompt to guide the child toward understanding what the correct response was.

5. **Inter-trial interval:** The inter-trial interval is a clear wait time that comes after the consequence to signify the end of a trial.

According to Smith (2001), by breaking down tasks into short, manageable trials and using suitable prompts and reinforcements, Discrete Trial Training maximizes children's success and minimizes their failures. However, DTT must be customized for each individual, since each child with autism exhibits a unique combination of deficits and demands specific intervention requirements (Lovaas, 1987; Smith, 2001).

ASD Definition and Characteristics

Autism spectrum disorders are a range of complex neurodevelopmental disorders, characterized by impairments in social interaction and communication and by restricted, repetitive, and stereotyped patterns of behavior (Centers for Disease Control and Prevention, 2012). Autism appears very early in life and is usually a lifelong condition. It affects information processing in the brain by altering how nerve cells and their synapses develop (Levy, Mandell, & Schultz, 2009). Although ASDs are neurodevelopmental disorders with strong genetic grounds, the exact neurobiological mechanism which causes autism is unknown (Schaefer & Mendelsohn, 2013). As a result, the primary form of diagnosis is through the observation of behavioral characteristics (Rosenberg & Schwartz, 2008).

According to a 2014 report from the Centers for Disease Control and Prevention (Centers for Disease Control and Prevention, 2014), the prevalence of ASD among children in the United States in 2010 was 14.7 per 1,000 children; that is equivalent to 1 in 68 children (1 in 42 boys and 1 in 189 girls) (Centers for Disease Control and Prevention, 2010). By comparison, 11.3 per 1,000 children with ASD were reported in 2008 (Centers for Disease Control and Prevention, 2008), and only 9.0 per 1,000 in 2006 (Centers for Disease Control and Prevention, 2006). Part of the change in prevalence over time can be associated with changes in diagnostic criteria for authism spectrum disporder. Increased awareness of autism over time is another factors that has contributed to the the rise in autism prevalence. An additional factor that has influenced the increase in autism prevalence is advanced parental age. Recent studies investigating the relationship between parental age and autism have demonstrated an increased risk of having a child with autism for older parents (Grether, Anderson, Croen, Smith, & Windham, 2009). The increasing prevalence of ASD in the population points to a need for the development of tools that will assist in teaching ASD students.

The American Psychiatric Association's *Diagnostic and Statistical Manual of Mental Disorders* is the standard reference for diagnosing mental and behavioral conditions. The APA published the fifth edition of its *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5) in May 2013. One of the main changes in DSM-5 compared to DSM-IV-TR is the modification in the definition of ASD, in part because of previous diagnostic shortcomings. The new definition has eliminated the previously separate categories of “Asperger syndrome” and “pervasive developmental disorder – not otherwise specified (PDD-NOS)” from the diagnostic manual and folded them together with “classic” autism into the single category of ASD. According to the American Psychiatric Association, a single umbrella disorder will improve the diagnosis of ASD without limiting the sensitivity of the criteria or substantially changing the number of children being diagnosed (American Psychiatric Association, 2013).

Children with “classic” autism exhibit significant language delays, social challenges, and stereotyped behaviors; some of them also have intellectual disability. Children with Asperger syndrome tend show milder symptoms: they typically do not display intellectual disability or problems with language, but have social challenges and stereotyped behaviors. Children who meet some of the criteria for autism or Asperger syndrome, but not all, may be diagnosed with PDD-NOS (pervasive developmental disorder – not otherwise specified). In addition, the APA’s DSM-5 has added social communication disorder as a new category that would allow for a diagnosis of disability in social communication without the presence of repetitive behavior.

Asperger syndrome and high-functioning autism present largely in the same way, and as a result, may be treated in a similar manner. Individuals affected by Asperger syndrome and high-functioning autism have average or above-average intelligence and struggle with the same issues related to social interaction skills or communication abilities (Howlin, 2003). The primary difference is that high-functioning autistic children show delayed language development skills, while in Asperger syndrome, the child does not show significant delays in language development.

APA's Diagnostic and Statistical Manuals IV and 5 (2000 and 2013) identify three main characteristics associated with autism spectrum disorders: social development problems, poor communication skills, and repetitive behaviors. Symptoms of social interaction impairment include difficulties with multiple nonverbal behaviors, such as eye-to-eye gaze, facial expression, body postures, and gestures to regulate social interaction. This impairment may also manifest as a failure to develop peer relationships appropriate to developmental level; a lack of spontaneous seeking to share enjoyment, interests, or achievements with other people; and a lack of social or emotional reciprocity. Symptoms of communication impairment include delays in the development of spoken language, the inability to initiate or sustain a conversation with others, stereotyped and repetitive use of language or idiosyncratic language, and lack of appropriate make-believe play or social imitative play. Lastly, symptoms of restricted and repetitive behavior include a preoccupation with one or more stereotyped and restricted patterns of interest, an inflexible adherence to specific but nonfunctional routines, the performance of stereotyped and repetitive motor actions, and a persistent preoccupation with parts of objects.

The American Psychiatric Association's *Diagnostic and Statistical Manual-IV, Text Revision: DSM-IV-TR* (2000) describes the standardized diagnostic criteria for autistic disorder ("classic" autism) as the presence of at least six symptoms total, including at least two symptoms of qualitative impairment in social interaction, at least one symptom of qualitative impairment in communication, and at least one symptom of restricted and repetitive behavior. Under the new DSM-5 definition, the diagnostic criteria are defined as three deficits in social communication, and at least two repetitive behaviors.

Social development deficits related to nonverbal behaviors are among the defining characteristics of ASD and impairments can vary greatly from child to child. Autistic children ages 3 to 5 are less likely than other children of the same age to exhibit social understanding, communicate nonverbally, understand facial expressions of others, imitate and respond to emotions, and approach others spontaneously (Cohen, Amerine-Dickens, & Smith, 2006).

According to Vicker (2009), communication within a social situation can be more challenging than just comprehending the words of others. There are unwritten rules that lead interactions and these may change in different situations and according to various circumstances. Children with autism spectrum disorder may lack social communication skills in varied areas. They may have difficulty staying on topic and be distracted by their own words or the dialogue of others. They may speak too loudly or too fast unless they are taught about others' communication needs. Many autistic children give minimal or even no eye contact during an interaction, since eye contact can be distracting or provide more sensory information than autistic children can process. Some may insist on talking about a favorite topic rather than participating in mutual communication. In some situations, they may talk aloud to themselves in public and be unaware that others can hear the content. They may make statements that are factually true but socially inappropriate because of their lack of awareness of the impact of their statements. Some children on the spectrum tell lies with the intent of getting people to leave them alone, rather than with the intent to deceive or manipulate. Many may have difficulty knowing that they need to provide sufficient information in order for their communication partner to understand the message. In addition, they may have difficulty surmising what information their communication partner already has and what new information is required.

Impairment of communication skills refers to autistic children's difficulty in acquiring speech and language. About a third to a half of autistic children do not develop enough natural speech capability to meet their daily communication needs (Noens, van Berckelaer-Onnes, Verpoorten, & van Duijn, 2006). This can range anywhere from a failure to develop functional speech to difficulties in developing spontaneous language. Other disabilities observed in the speech of children affected with autism include echolalia and pronoun reversal. Echolalia is the immediate and involuntary repetition of words or phrases just spoken by others. Pronoun reversal refers to confusing first and second person pronouns in speech. Echolalia and pronoun reversal hinders individuals' ability to conduct functional communication in order to make requests or share experiences (Tager-Flusberg & Caronna, 2007).

Children with ASD often show deficits in joint attention, which is a necessary component for functional speech (Johnson & Myers, 2007). Joint attention refers to the ability to focus attention between interacting partners on objects and events. For instance, when someone is pointing at an object, autistic children may look at the pointing hand instead of focusing their attention on the object being pointed to. Lack of joint attention in children with autism can prevent them from being able to engage in a conversation or attend to an activity with another person.

Repetitive or restricted behavior can manifest in different forms among children diagnosed with ASD. Some examples of this behavior are insisting upon having everything in the same place all the time, lining up toys, spinning objects, rocking back and forth, and hand flapping. Children affected with autism may engage in different levels of repetitive behavior, ranging from persistent preoccupation with parts of objects to violent self-destructive behaviors, such as head banging. For children with ASD, repetitive behaviors or *perseveration* can be a source of enjoyment and a way to cope with everyday life (Richards, Oliver, Nelson, & Moss, 2012). Perseveration can even play an advantageous role for people with autism, since it may relate to a passionate interest, such as computer gaming, which can lead to friendships.

The core cognitive deficits typically exhibited by children with ASD are considered in three domains: Theory of Mind (false-belief understanding), where autistic children are unable to recognize that other people have thoughts, feelings, and intentions that are different from their own, and as a result, fail to predict people's behavior based on their thoughts, feelings, and intentions; Executive Functioning, where autistic children show problems with organizing thoughts and actions, planning, sequencing (what to do next), and sustaining attention towards some goal; and Weak Central Coherence (enhanced local information processing), where autistic children fail to bring together various details in order to make a meaningful whole, such as detecting the parts of objects and paying attention to minor details, but failing to see how these details fit into a bigger picture (Pellicano, 2010).

In her study, Pellicano (2010) found that the cognitive characteristics in autism spectrum disorders vary from one child to the next. For instance, while one child with ASD showed difficulties in Theory of Mind alone, another child showed problems in Theory of Mind *and* Executive Functioning. As a result, while Theory of Mind, Executive Functioning, and Weak

Central Coherence exist across the diagnoses for ASD, they are not persistent across all children within a diagnosis.

According to Begeer et al. (2011) Theory of Mind can be taught by having the child focus on distinguishing between fantasy and reality, learning to assess a social situation and recognize another person's intentions and emotions (such as happiness, anger, fear and sadness), and participating in experiments that involve placing oneself in the thoughts and feelings of another person (first-order mental state reasoning) as well as second-order mental state reasoning, (for example, "Where does Sarah think that Mark thinks he will find the toy?").

Executive Functioning issues, according to Wertz (2012), can be addressed through activities that require organizing and remembering the steps to complete a task, matching exercises, sequencing tasks, and selective attention exercises, depending on the child's specific deficiencies. One example of such activities is having the child identify an object and then asking them to point to the same item on the table among an array of a few other items.

Weak Central Coherence in children with autism can be identified using the Hooper Visual Organization Test, in which line drawings depicting simple objects are arranged in a puzzle-like fashion and the participants are asked to conceptually integrate the fragments in order to identify the object (Jolliffe, 2001). According to Lopez and Leekam (2003) central coherence issues can be facilitated by providing context information, presented either visually or verbally. Children with autism are able to process globally when they are instructed using visual or verbal context; however, they tend to process information locally when no such instructions are offered.

According to Rosenberg and Schwartz (2008), autism, particularly in the area of cognition, is characterized by an uneven rather than a delayed development. Thus, it is common for a child with ASD to be highly capable in some tasks, such as math computation, but unable to carry on a conversation or follow simple routines independently. As a result, autistic children require customized training that can support their unique deficits.

Problem Description

The majority of autism interventions rely on physical objects for delivering instruction. Physical objects such as flashcards are difficult to organize and manage. Searching for a desired picture can be time-consuming, and organizing flashcards in an appropriate manner can be frustrating. Unlike software, flashcards deteriorate with use, and as a result, need to be replaced quite often. Digital applications can ameliorate this problem by providing programs that can be customized repeatedly and reused over time.

Autism interventions also require educators to conduct instruction consistently, avoiding subtle changes across trials. However, delivering instruction in exactly the same manner each time is almost impossible for human beings. Training the parents of autistic children to deliver this type of instruction at home is even more difficult to achieve. On the other hand, computer applications can provide consistent accuracy, which can result in higher intervention effectiveness (Ramdoss et al., 2011).

Research on the efficacy of iPad devices for teaching children with ASD suggests that iPad devices can increase intervention effectiveness (Keay-Bright and Howarth, 2011; Sitdhisanguan et al., 2012; Venkatesh et al., 2012; Fernández-López, et al., 2013; Kagohara et al., 2013; Lee et al., 2013; Jowett et al., 2012; Cardon, 2012a; 2012b; King et al., 2014). Even autistic children understand the concept of direct manipulation on multi-touch interfaces quite intuitively (Hayes et al., 2010; Price, 2011; and Venkatesh et al., 2011), and they are more comfortable interacting with predictable devices than interacting with humans (Shah, 2011; Stahmer, Schreibman, & Cunnigham, 2011; Sitdhisanguan et al., 2012). As a result, intuitive mobile applications that provide a learning platform for children with autism may prove valuable in interventions.

As new forms of technology penetrate people's lives, new means of interaction become necessary for the communication of people's needs and desires. Although computer technology is already being implemented in training autistic children, there is little research in the autism literature about the role of technology in addressing nonverbal behaviors related to social interactions. Furthermore, no mobile application has yet been designed with a focus on instruction regarding the nonverbal gestures that are used in daily social communication.

Statement of Purpose

The purpose of this project is to create a mobile platform for teaching nonverbal social communication skills to high-functioning autistic children. The application uses the established method of Discrete Trial Training to deliver customizable programs that can be tailored to the unique needs of children with autism spectrum disorder (ASD). These programs can be easily customized by specialists and remotely shared with parents over the Internet to enable them provide the same exercises to their children at home. In addition, children’s progress is automatically monitored and recorded for planning and adjustment of the training program.

Chapter 2: Literature Review

According to the Technology-Related Assistance for Individuals with Disabilities Act of 1988 (29 U.S. Code § 2202), an assistive technology is defined as any item, piece of equipment, or product system that is used to increase, maintain, or improve the functional capabilities of individuals with disabilities. Assistive technologies include a wide range of solutions, from paper cards to cutting-edge computer-based technology.

Low-tech assistive technologies are intervention methods that mostly have a simple paper- or cardboard-based form. Research shows that children with autism tend to process visual information easier than auditory information (Michel, 2004). Although low-tech interventions are effective in supporting autistic children's learning needs, they are often complex and require low student-to-teacher ratios, as well as specific procedures to train educators, and many hours per week of intervention (Lang, Machalicek, Rispoli, & Regester, 2009). In settings where resources may be scarce, such as group homes, schools, and the children's own homes, these complexities may present logistical obstacles to the accurate implementation of communication interventions and reduce intervention effectiveness (Ramdoss et al., 2011).

The use of computer-assisted interventions enables the development of skills in a highly standardized, predictable, and controlled environment, which meets the ASD need for sameness while at the same time eliminating the social complexities of interaction with others (Stahmer, Schreibman, & Cunningham, 2011). Children with ASD often express relatively strong visual processing skills and an interest in visual media, and as a result, computer-assisted interventions may be particularly appropriate and motivating for children on the spectrum (Shane & Albert, 2008). Computer-based tasks can be repeated with very little change from one exercise to the next. Software does not get impatient with repetition, and therefore can be implemented to provide prompts and reinforcement consistently (Putnam & Chong, 2008). Computer-assisted interventions provide the one-on-one structured learning environment that is often required for children with ASD to learn a topic (Williams, Wright, Callaghan, & Coughlan, 2002). Computer-assisted interventions also allow children to work at their own pace (Putnam & Chong, 2008). As a result, although computer-based instructions do not necessarily increase learning performance in autistic children, they significantly reduce disruptive behaviors and increase compliance with instructions (Parsons, Mitchell, & Leonard, 2004).

Putnam and Chong (2008) performed a survey of "software and technologies designed for people with autism," to identify how technology is integrated into the lives of children with autism and their families. The survey investigated users' goals when considering a technology or software and found that ASD users' goals mainly fall into three domains: social communication, academic support, and scheduling/organization. Their study did not find any correlations between user information (gender, verbal ability, diagnosis, and age) and social communication or scheduling/organization goals, indicating that these goals were shared equally in the ASD user population. However, they found a significant difference related to goals pertaining to academic technologies for ASDs diagnosed with PDD-NOS, suggesting that this group of ASDs are disproportionately concerned with academic goals when considering software and technology. User suggestions included making products more portable, making input devices easier to use, allowing customizations for color and sound sensory information, and designing software with fun in mind (i.e., creating learning experiences as games). The researchers concluded that technology was as a major interest for people dealing with autism.

In a study by Williams, Wright, Callaghan, and Coughlan (2002) the development of reading skills was evaluated in eight children with autism, aged 3-5 years, using computer-assisted learning compared to book-based learning. Children were randomly assigned to either the computer-assisted or book-based learning for a 10-week course of study. These researchers concluded that children with autism spent more time on reading material when they accessed the material through a computer and were less resistant to its use.

Ramdoss et al. (2011) performed an analysis of the studies conducted between 1990 and 2011 that involved the use of assistive technology in teaching communication skills to children with autism spectrum disorders. They examined 10 studies that provided intervention to a total of 70 autistic participants with ages ranging from 3 to 14 years. Various communication skills were measured in these studies, and most studies targeted multiple communication skills. Five of the studies evaluated changes in receptive language after using computer-assisted interventions to teach new vocabulary words (Bosseler & Massaro, 2003; Coleman-Martin et al., 2005; Hetzroni

& Shalem, 2005; Massaro & Bosseler, 2006; Moore & Calvart, 2000). Two studies were designed to increase the frequency of vocal imitation: Bernard-Opitz et al. (1999) focused on the imitation of syllables, and Heimann et al. (1995) focused on the imitation of spoken sentences. Six studies were designed to increase the frequency of spoken words (Bosseler & Massaro, 2003; Massaro & Bosseler, 2006; Heimann et al., 1995; Hetzroni & Tannous, 2004; Parsons & La Sorte, 1993; Simpson et al., 2004). One study taught phonological awareness (Heimann et al., 1995), and another one taught responding to questions (Parsons & La Sorte, 1993). Two studies aimed at improving communication by decreasing echolalia and other inappropriate speech (Hetzroni & Tannous, 2004; Parsons & La Sorte, 1993). Three studies taught social and conversational initiations (Hetzroni & Tannous, 2004; Parson's & La Sorte, 1993; Simpson et al., 2004).

According to Ramdoss et al. (2011), all these studies reported that computer-assisted interventions positively affected participants' improvement on communication-dependent variables. Studies that evaluated the effect of computer-assisted interventions across time found that technology was associated with improvements in participants' number of vocabulary words (Bosseler & Massaro, 2003), words correctly identified (Moore & Calvart, 2000), correct matches between text and food items (Hetzroni & Shalem, 2005), sentence imitation (Heimann et al., 1995), phonological awareness (Heimann et al., 1995), verbal expression (Heimann et al., 1995), communication initiations, and relevant speech and social greetings (Hetzroni & Tannous, 2004). Also, studies showed that computer-assisted interventions were associated with decreases in delayed echolalia, immediate echolalia, and irrelevant speech. One limitation of these studies, however, is that their research focused only on communication deficits related to ASD; they did not examine the role of technology in ameliorating social interaction impairments and symptoms of restricted and repetitive behavior related to autism.

Another study involving speech skills, by Bernard-Opitz, Sriram, and Sapuan (1999), evaluated the effect of computer-assisted instructions in promoting vocal imitation in comparison to teacher-implemented instructions. Results from their study revealed greater improvements in the computer-assisted instruction condition compared to teacher-implemented instructions.

Bernard-Opitz, Sriram, and Nakhoda-Sapuan (2001) conducted a study to evaluate the effectiveness of computer interfaces for teaching social problem-solving strategies to pre-school children with ASD. In their study, they presented eight different social conflicts involving taking turns, communicating, and bargaining to assess autistic children's progress compared to their neurotypical peers. Although the children with autism produced significantly less appropriate solutions compared to their normal peers during the training sessions, the autistic group displayed significant improvements as the program progressed. These results suggest that young children with autism, as well as their normal peers, could benefit from computerized training in social problem-solving.

Beaumont and Sofronoff (2008) conducted a study to investigate the effectiveness of a combined computer-based learning program in teaching social skills and social understanding to children with autism. In their study, both human and computer-animated characters were utilized to teach emotion recognition and social problem-solving. Forty-nine children with Asperger syndrome participated in the study; about a half were randomly assigned to the intervention and the other half were used as the control group. Results indicated significant improvements in social functioning for the participants over the course of the intervention. Treatment-group participants also showed better scores in suggesting appropriate emotion-management strategies. However, the study did not show any difference in the improvement of facial expression and body-posture recognition skills between the children in the intervention and the control group. The study concluded that the computer-based program was effective in enhancing the social skills and emotional understanding of children with Asperger syndrome, but not effective in teaching facial expressions and recognizing body-postures.

Parsons, Mitchell, and Leonard (2004) investigated the potential of using virtual reality technology to simulate various real-life environments for teaching social awareness and social behaviors to individuals with ASD. The use of three-dimensional virtual reality allows for examining the development and practice of social skills in a highly realistic—but controlled—environment. Results from this study indicated that participants were able to learn to effectively use this technology and to understand that the virtual environments were representations of real world situations. In another study, the same researchers examined the use of virtual reality for teaching social skills in a virtual café setting, where users were able to practice making judgments and reasoning around social interactions. Their results showed several instances of significant improvement in judgments and explanations for social rules, such as where to sit (Parsons, Mitchell, & Leonard, 2007). These two studies demonstrated the potential of virtual reality for teaching social skills.

Several studies have investigated the benefits of mobile devices, tangible user interfaces, and multi-touch screens to increase comprehension, communication capabilities, and social skills in children with autism. According to Keay-Bright and Howarth (2011), tangible interfaces reduce the demand on the cognitive system by providing people with opportunities to intuitively interact through the senses. Dourish (2001) describes this as *embodied interaction*, meaning bodily instincts and sensory perception provide vital clues on how to interact. Embodied interaction is based on the understanding that users create and communicate meaning through their interaction with the system. Tangible interfaces capitalize on the tactile and physical skills that people employ in dealing with the world around them.

Sitdhisanguan, Chotikakamthorn, Dechaboon, and Out (2012) conducted an empirical study to learn the efficacy of computer-assisted interventions using tangible user interfaces compared to pointing-device interfaces for children with autism. In their study, elementary skill instruction was used to measure the performance of their tangible user interface. Empirical results from their study showed that the touch-based, tangible user interface offered much better ease-of-use performance than that of the mouse-based system. Regarding learning efficacy, experimental results showed that the tangible user interface system resulted in higher skill improvement as compared with the mouse-based system and a non-computer training method (Sitdhisanguan et al., 2012).

Venkatesh, Greenhill, Phung, Adams, and Duong (2012) developed a mobile framework for delivery of early intervention therapy on multi-touch interfaces using Discrete Trial Training. Lessons were provided in the form of imitation, matching, receptive, expressive, or natural environment tasks. The researchers asked therapists and parents to evaluate their framework. Qualitative evaluation on a scale from 1 (worst) to 5 (best) by two therapists with more than 15 years experience in therapy showed an average of 4.2 and 4.5 respectively (therapists 1 and 2) on stimulus complexity, stimulus presentation, prompts, and reinforcements' quality of adaptation. Parents were asked to evaluate the quality of both of their own teaching experience with the system and their child's learning experience. Results of this survey were overwhelmingly positive in all aspects being assessed, both for the child and the parent. Of the seven parents who returned the survey, only one reported an average experience, while all others rated most experiences with the highest score. The assessments of the children's experiences showed that, using the framework, children were able to learn from the first failed attempt at a task. On average, across all participants, 13% of tasks initially failed were eventually completed with some level of prompting, while 40% of tasks initially failed were completed without any prompting. Results also showed that the majority of tasks initially requiring prompting were either ultimately completed without prompting or were completed with a lower level of prompting, proving the framework effective in training children with autism.

Three studies have been conducted to evaluate the effectiveness of the Proloquo2Go iOS app for teaching communication skills to children with autism as compared to a picture-exchange system and manual signing (van der Meer, Kagohara, et al., 2012; van der Meer, Sutherland, et al., 2012; van der Meer, Didden, et al., 2012). These investigations aimed at using Discrete Trial Training to teach children to request preferred stimuli by selecting icons from the screen of an iOS device (iPod Touch). Procedures involved offering preferred items, verbal cueing ("Let me know if you want something"), time-delay, graduated guidance, and appropriate reinforcement. To evaluate the effects of the teaching procedures, each study used a multiple-baseline-across-participants design. In addition, to compare acquisition of the two or three communication methods, an alternating treatments design was employed. The studies also included assessments to determine which communication method children preferred to use. Results from these studies indicated that all four children learned to use the Proloquo2Go app and picture-exchange system, but only two learned to use manual signs. Three of the four children showed a preference for using the iOS device with the Proloquo2Go app and showed better maintenance of their newly acquired requesting skills with their preferred system. As a result, these three studies provide evidence that Discrete Trial Training procedures were successful in teaching autistic children with communication developmental disabilities to use iOS devices with the Proloquo2Go app to make requests for preferred items. However, a major limitation of these studies is their small sample size (only four subjects), which does not allow for the generalization of targeted skills to all children with an autism spectrum disorder diagnosis.

Fernández-López, Rodríguez-Fórtiz, Rodríguez-Almendros, and Martínez-Segura (2013) performed a study to investigate the efficacy of a mobile app based on Apple iOS devices, called Picaa, for children with special needs (autism, Asperger syndrome, Down syndrome, etc.) for four types of educational activities: exploration, association, puzzles, and sorting. These four categories were intended to cover a set of learning objectives that included memory (hearing, visual, short-term, and working), hand-eye coordination, communication, vocabulary, attention, perception, cause-effect relationships, interpretation, priority, examination of assumptions, language (reading, writing, oral, syntax, semantics, and pragmatics), and calculations or strategies for problem-solving. The study involved using the Wilcoxon signed-rank test with 39 subjects. Results from this study proved that the use of Picaa was associated with positive effects in the improvement of learning skills, including language, math, environmental awareness, autonomy, and social skills. Their study also found that the use of touch-based devices and multimedia contents increased children's interest in learning and their attention.

Kagohara et al. (2013) conducted a systematic review of 15 empirical studies on the use of Apple iOS devices in teaching programs for individuals with a diagnosis of autism spectrum disorder and/or intellectual disability (Achmadi et al., 2012; Flores et al., 2012; Kagohara, Sigafoos, et al., 2012; Laarhoven et al., 2009; Burke et al., 2010; Cihak et al., 2010; Hammond et al. 2010; and Kagohara, 2011). The review covered studies in five domains: academic, communication, employment, leisure, and transitioning across school settings. The 15 studies reported largely positive outcomes for 47 participants, suggesting that iOS devices are viable technological aids for individuals with autism spectrum disorder. The review also found that iOS devices are readily available, relatively inexpensive, and appear to be intuitive to operate. Such devices seem to be socially accepted and, as a result, were considered more favorable as assistive technology tools by individuals with developmental disabilities: the participants in these studies largely preferred using such devices over low-tech options. But the reviewers also concluded that, while the studies up to June 2012 covered a number of priorities for individuals with autism, there are noticeable limitations in the types of skills that have been targeted. Only a few studies addressed academic and employment skills, and no studies addressed social skills. The studies that focused on nonverbal communication skills were limited to naming pictures or requesting access to preferred stimuli.

King, Thomeczek, Voreis, and Scott (2014) conducted a study to explore how iPads were being used by children and young adults with ASD in classroom settings. This study involved six subjects using six iPads for a total of 202.6 minutes over the course of 3 months in their classrooms. The researchers observed 28 apps classified into the following 3 categories: augmentative and alternative communication (AAC) apps (i.e., using iPad as a speech-generating device), academic apps (i.e., targeting a specific language, literacy, or academic topic), and game apps (i.e., for entertainment). The study aimed at determining whether or not the app was used in a way that was consistent with its intended function ("fulfilled") by examining the percentage of time spent on different apps. The percentage of app function fulfillment showed highest for game apps (72%), followed by academic apps (63%), and AAC apps (35%). The data from their study suggested that iPads are being used in schools appropriately to support children and young adults with ASD.

Lee et al. (2013) conducted a comparative study to assess the relative effects of iPad-assisted interventions compared to traditional teacher-based approaches. The researchers used the iPad's Photos app and See.Touch.Learn app to display images on an iPad versus printed images presented by a therapist. A correct response was defined as independently identifying the correct photo displayed on the iPad or the correct printed photo card (in the therapist-only condition, identification was by touching the picture or saying the name of the verb-noun action displayed in the picture). The researchers measured the following: percentage of intervals with on-task behavior; percentage of intervals with challenging behavior; time required to complete assignments; and percentage of independent correct. Interventions were provided using Discrete Trial Training. Results from the study demonstrate that the iPad was associated with shorter intervention sessions, more time on-task, and less challenging behavior for one participant (with no difference between conditions for the second participant). Their study suggested that iPad-assisted interventions are as effective as teacher-based interventions and in some cases may even result in improved performance compared to teacher-based interventions. However, this study had several limitations, including a small sample size (two subjects), lack of a baseline to identify how much learning occurred in either condition, and the lack of counterbalancing to account for the skill improvements gained from one approach prior to conducting the second intervention.

Jowett, Moore, and Anderson (2012) evaluated the effectiveness of a video-modeling intervention to teach basic numeracy skills to a 5-year-old boy diagnosed with autism. They used video clips that depicted writing Arabic numerals 1-7 and measured the subject's ability to identify, write, and comprehend the quantity of numbers. Their baseline measures for all numbers were obtained by instructing the subject to write each numeral three times on sheets of paper. The effectiveness of the experiment was tested by the observed generalization of the behavior across settings and stimulus materials, and follow-up data that were gathered 2, 3, 4, 5 and 6 weeks after the conclusion of the intervention. The study found clear gains in the subject's ability to identify and write the Arabic numerals 1-7 and comprehend the quantity of each numeral. The researchers concluded that iPad-based video modeling can be an effective technique for teaching numeracy skills to children with autism. However, this study included only one subject, and systematic replication of the study with different participants is required to validate their findings.

Cardon (2012) conducted a study to investigate the functional relation between using an iPad for video-modeling training and increased imitation skills in preschool children with autism. Four subjects (2 boys and 2 girls) with an autism spectrum diagnosis participated in the study. Scenarios included activities and routines that the caregivers selected for their children, such as pat the baby doll, wipe her face, make the bed, etc. This study found that children with ASD prefer learning adaptive skills through video presentations over following a teacher's instructions. Recording such videos was a tedious and time-consuming task with traditional media, but state-of-the-art mobile technology (such as iPads) allows this task to be carried out easily. Results from the study indicate that all caregivers were able to successfully create video models on an iPad with minimal training. All the children in the study made substantial advances in their imitation skills during caregiver-implemented treatment. Post-treatment studies indicated that the acquired skills were maintained and generalized to imitation of live models. It was also found that generalization happens more consistently and is retained for a longer time with video modeling as compared with teaching by a live person.

Murdock, Ganz, and Crittendon (2013) investigated the use of an iPad play story to increase the play dialogue of four autistic preschool children. The play story provided a computer-delivered slideshow of a narrative play with scripted dialogue. The procedure differed from video modeling in a few key ways. The slideshow allowed users to easily navigate to a specific part of the story or choose to advance through it in a linear fashion. In addition, no movement of the characters was depicted and the audio was provided in a pretend play voice so the result was more like a storybook with audible character dialogue. Results from this study showed that three of the participants demonstrated increases in the target behavior and moved beyond a reliance on the scripted dialogue, producing their own novel play dialogue. Visual analysis reflected sustained increases in the target behavior and little overlap with baseline data. They concluded that visual strategies increase the independence of autistic children by allowing them to complete tasks without adult direction.

In summary, according to the articles reviewed for this study, 12 cases of computer-assisted interventions conducted on a desktop computer have displayed positive effects in providing autism interventions. In addition, 17 articles described studies on iPad applications; in 15 cases, these have shown evidence for positive effects in providing iPad interventions to children with ASD. Table 2.1 displays a visual summary of the literature on computer/iPad interventions.

Table 2.1

Summary of the Literature

Medium	**Variables**	**Association**	**Articles**
Desktop Computer	Time on task reading a book and the number of spoken words	+	Williams, et al. (2002)
	Words correctly identified	+	Moore and Calvart (2000)
	Number of vocabulary words	+ + +	Bosseler and Massaro (2003) Coleman-Martin, et al. (2005) Massaro and Bosseler (2006)

	Correct matches between text and food items	+	Hetzroni and Shalem (2005)
	Communication initiations, relevant speech, and social greetings	+	Hetzroni and Tannous (2004)
	Social problem-solving strategies	+	Bernard-Opitz, et al. (2001)
	Vocal imitation	+	Bernard-Opitz, et al. (1999)
	Social functioning and emotion-management Facial expression and body-posture recognition	+ -	Beaumont and Sofronoff (2008)
	Social awareness and social behaviors	+	Parsons, Mitchell, and Leonard (2004)
	Judgments and reasoning about social interactions	+	Mitchell, Parsons, and Leonard (2007)
iOS Device	Qualitative evaluation of their mobile platform	+	Venkatesh, et al. (2012)
	Communication skills (request preferred stimuli by selecting icons from iPad)	+ + + + -	van der Meer, Kagohara, et al. (2012) van der Meer, Sutherland, et al. 2012) van der Meer, Didden, et al. (2012) Achmadi et al. (2012) Flores et al. (2012)
	Language, math, environmental awareness, autonomy and social skills	+	Fernández-López, et al.(2013)
	Spell checking	+	Kagohara, et al. (2012)
	Task completion (cleaning bathroom, mop floor/empty garbage, clean kennels)	+	Laarhoven, et al. (2009)
	Appropriate responses to fire safety training	+	Burke, et al. (2010)
	Transition between school locations	+	Cihak, et al. (2010)
	Independently watch a movie, listen to music/songs, and look at pictures	+	Hammond, et al. (2010)
	Independently operate an iPod Touch to watch movie	+	Kagohara (2011)
	Time on-task, challenging behavior time, task completion time, and correct responses	-	Lee et al. (2013)
	Writing skills	+	Jowett, et al. (2012)
	Social stories (pat the baby doll, wipe her face, make the bed, etc.)	+	Cardon (2012)
	Play story dialogue creation	+	Murdock, et al. (2013)

Note: + means evidence for positive association on the variables; - means evidence for no association

In examining the literature, it is clear that a major limitation in many of these studies is their small sample size. It is not valid to generalize findings based on the evaluation of such a small number of participants. In addition, it is difficult to draw reliable conclusions about possible child, family, or environmental variables associated with the results when most studies involve such small numbers of participants. According to Howlin, Magiati, and Charman (2009), when the sample size is small, it is even more important that the study contains highly detailed information on individual differences in order to ensure that group differences are not due mainly to improvements in a small subgroup of individuals. Although computer-assisted interventions are highly effective for some children, gains are not universal, and some children make only modest progress, while others show little or no change (Howlin, Magiati, and Charman, 2009). Furthermore, the majority of these studies do not assess the generalization of targeted skills to real-life social contexts. Additional research on the generalization of computer-assisted interventions for individuals on the autism spectrum is required to better evaluate the efficacy of such technology in teaching functional social abilities to children with ASD (Wainer & Ingersoll, 2011).

Despite the limitations of the current literature, a review of the literature does suggest that computer-assisted interventions and iOS devices *may* increase intervention effectiveness for teaching children with ASD. These devices provide consistent accuracy in implementing interventions, which can result in higher intervention effectiveness (Ramdoss et al., 2011). Device-enabled interventions also provide a highly standardized, predictable, and controlled environment that addresses the ASD need for sameness (Stahmer, Schreibman, & Cunnigham, 2011). The use of these devices supports the visual processing skills of autistic children, as well as their interest in visual media, and as a result, may be particularly appropriate and motivating for children on the autism spectrum (Shane & Albert, 2008). Among various computer-assisted interventions, touch-based devices offer much better ease-of-use performance than mouse-based desktop systems or laptops with a touchpad (Shah, 2011; Sitdhisanguan et al., 2012). In addition, touch-based interfaces offer instant gratification for autistic children with limited patience or those who can't interpret the connection between a mouse and computer screen (Shah, 2011). According to Shah (2011) and Kagohara et al. (2013), mobile devices can offer a sense of independence to children with social and communication deficiencies. Mobile devices can easily and cheaply replace the bulky and expensive older forms of assistive technology that these children had to employ in the past. Furthermore, mobile devices allow children to work at their own pace (Putnam & Chong, 2008) and support learning at any time and in any location.

Nonverbal Social Communication Skills

Social communication skills are functions that relate to the use of verbal and nonverbal communication for social purposes, such as greeting or sharing information, in a manner that is appropriate for the social context. These skills include the ability to change communication to match context, such as speaking differently in a classroom than on the playground; following rules for conversation and storytelling, such as taking turns in conversation; and understanding what is not explicitly stated, such as idioms, humor, metaphors, and multiple meanings that depend on the context for interpretation (American Psychiatric Association, 2013).

Gestures are a means of nonverbal social communication and are defined as actions related the movement of fingers, hands, and arms with the intention to communicate. According to Beattie (2004), they are different from other body language by having greater association with speech and language. While the rest of the body can indicate more general emotions, gestures have specific linguistic content. Gestures are carried out in three phases: preparation, stroke, and retraction. The stroke contains the actual message, while the preparation and retraction consist of moving the arms from the rest position and bringing them back.

Children with autism display significant impairment in their use of gesture (Rogers et al., 2003). These deficits, however, do not appear to be a result of insufficiency in gesture recognition abilities (Ingersoll, Lewis, & Kroman, 2007). Furthermore, according to Rogers et al. (2003), impairment in overall gesture imitation ability is accounted for neither by a lack of motor functioning skills nor by a lack of social development capabilities. In children with autism, impairment in the use of gesture has been found to be highly correlated with communication skills related to concurrent language ability (Sigman & Ungerer, 1984). Research suggests that the improvement of gesture imitation abilities may improve language and social skills, and as a result, should be an important focus of early intervention programs (Rogers et al., 2003; Ingersoll, Lewis, & Kroman, 2007).

There are several types of gestures according to Beattie (2004) and Goodwin (2003). Gestures that relate to nonverbal social interactions can be grouped into the following categories:

1. **Symbolic:** Symbolic gestures are close to sign language and are used as substitutes for words. For example, holding up the hand with all fingers closed except for the index and second finger can mean "victory" or "peace."
2. **Iconic:** Iconic gestures add detail to the mental image that the person is trying to convey and are used to illustrate what is being said. For example, using the hands to show how big or small an object is.
3. **Metaphoric:** Metaphoric gestures are used to shape the idea being explained. They include specific shapes, such as finger pinches and physical shaping, or gesturing upward to indicate high value, rank, etc.
4. **Deictic:** Deictic gestures also known as pointing gestures indicate real, implied or imaginary persons, objects, directions, etc.
5. **Beat:** Beating of a finger, hand, or arm to make a particular point. A short, single beat to mark an important point in a conversation or repeated beats to express a critical concept are examples of beat gestures.

According to Bruner (1981), the functions of gestures as related to ASD include behavior regulation, joint attention, and social interaction. These are explained as follows:

Behavior regulation gestures: Behavior regulation gestures are used to manage the behavior of another person, such as requesting an object or requesting an action. For example, holding up a hand with the palm facing out asks the other person to stop doing an action, while putting another person's hand on a container might request the person to open it.

Joint attention gestures: Joint attention gestures are used to direct or share another person's attention to an object or event, such as pointing and looking at an airplane in the sky (Colgan et al., 2006).

Social interaction gestures: Social interaction gestures are gestural acts used to attract or maintain others' attention for social purposes, including greeting, requesting permission, or acknowledging another. Examples of social interaction gestures, according to Colgan et al. (2006), are waving "hi" or "bye," requesting games or routines, and shaking the head for "yes" or "no." In their sample of 9- to 12-month-old infants, Colgan et al. (2006) examined the emergent use of social interaction gestures in infants later diagnosed with autism. This study found that children who use fewer diverse types of social interaction gestures are significantly more likely to be diagnosed with autism.

According to Venkatesh et al (2012), activities in training programs that focus on nonverbal behaviors related to social interactions can be divided into a number of skill sets:

Matching exercises: Matching exercises can be used to teach several types of skills, including receptive and expressive language skills. Receptive language skills require the child to respond receptively to language. An example would be for the application to say the name or the sound of a gesture and to request the child to touch the target picture. Expressive language skills require the child to use language expressively. An example would be displaying a gesture and having the child name it. Matching activities rely on relationships between concepts and can be used to teach an array of various skills (Venkatesh et al., 2012).

Imitation skills exercises: Imitation skills require the child to imitate gestures. These gestures are either acted by the trainer or demonstrated by an animation or a video of a real person. Video-modeling instruction is an example of an imitation skills exercise (Venkatesh et al., 2012).

Natural environment exercises: These exercises teach context and relate a concept to real-life experiences by suggesting task-coordinated activities to be performed by the child and parent in the real world. Natural environment tasks are important for concept generalization and extending the skills to the child's day-to-day social activities. Natural environment tasks prepare the parent with a knowledge of why the skill is important via text and video recordings of therapists, who are presented as a model to copy from, and present a list of key elements to look for in an activity (e.g., pointing). The activity is performed in the real world, responses are recorded on the iPad, and prompting is done by the application or parent (Venkatesh et al., 2012).

Children with impairment in use of nonverbal behaviors related to social interactions lack the necessary behavioral skills to interact with others according to social convention, a deficit that affects both academic and social development (Rao, Beidel, & Murray, 2007). These skills are necessary for developing appropriate and functional interactions, and as a result, several types of therapies have been designed for helping autistic children improve those deficits. Autism therapies that are currently used to help address the core features of ASD are described in the next section.

Autism Therapies

Autism therapies attempt to improve the core deficits and abnormal behaviors associated with autism spectrum disorders (ASD), and to increase the quality of life and functional independence of autistic individuals. Therapies try to achieve this goal by minimizing the core features of ASD, facilitating development by education, improving social and communication skills, and training families. A large number of interventions are currently used to help address the core features of ASD: impairment in social skills, communication deficiencies, and restricted, repetitive behaviors. Autism therapies can be grouped into two major categories: biologically based interventions and educational interventions. Educational interventions include behavioral, developmental, and combined interventions (Roberts & Prior, 2006). Discrete Trial Training, which is the focus of this project, is a behavioral intervention and is one of several methods for teaching children with autism. This section provides an overview of the different instructional methods for training young children with autism and discusses their efficacy.

Biologically Based Interventions

Although various medications have been used to treat the symptoms of autism, there is still no medical treatment for the core features of autism. The currently used medications attempt, in general, to reduce anxiety and attention deficit hyperactivity disorder (ADHD) in autistic children and to increase children's benefit from concurrent educational interventions. According to Roberts and Prior (2006), a number of medications have been demonstrated to be somewhat effective for individuals with autism, including neuroleptics/antipsychotics (such as risperidone), selective serotonin reuptake inhibitors (SSRIs), antidepressants, stimulants, and anticonvulsants. At the same time, several medications have been demonstrated to be ineffective and/or harmful for children and adolescents with autism, including naltrexone, secretin, and adrenocorticotropic hormone (ACTH). Complementary and alternative interventions, such as diets (casein-free and gluten-free), anti-yeast therapies, and chelation therapy, are also considered in the category of biologically based intervention; however, there is minimal evidence demonstrating the effectiveness of these interventions.

Educational Interventions

Early educational interventions play a major role in improving the core deficits of ASD. The goals of treatment are to maximize independent functioning and improve quality of life. There are several educational intervention methods available that focus on academic learning, socialization, adaptive skills, communication, improvement of repetitive behaviors, and generalization of abilities across multiple environments (Myers & Johnson, 2007). According to Cervera et al. (2011), the educational interventions can be classified as behavioral, developmental, or combined. A summary of empirical studies supporting the efficacy of behavioral interventions is provided in the next section.

Behavioral Interventions

Interventions based on Applied Behavior Analysis (ABA) were pioneered by Ivar Lovaas and colleagues in the 1960s. ABA focuses on improving children's communication delays, social skills, and emotional characteristics, and suggests that most human behavior is learned through the interaction between an individual and his or her environment (Roberts & Prior, 2006). "Interventions based on ABA, particularly those involving home therapy and beginning in the preschool years, have been most comprehensively studied and, as a consequence, have the best established evidence base" (Howlin, Magiati, & Charman, 2009).

Simply put, behavioral interventions are based on the idea that children are more likely to learn and retain behaviors for which they receive positive reinforcement (reward) and are less likely to learn or maintain behaviors for which they receive no reward (including punishment). Behavioral interventions aim to teach and increase targeted positive behaviors and reduce or eliminate inappropriate or non-adaptive behaviors through careful manipulation of the environment and the provision of contingencies (Roberts & Prior, 2006). Applied Behavior Analysis and Discrete Trial Training (DTT) constitute the core features of most behavioral intervention programs.

Behavioral intervention therapies—also referred to as Early Intensive Behavioral Interventions (EIBIs)—should begin as early as possible, preferably by the age of 3. They should be carried out for approximately 40 hours per week and last for at least 2 years. Treatment sessions are provided in a one-on-one discrete trial format and focus on the systematic teaching of measurable behavioral units, repetitive practice, and structured presentation of tasks that progress from simple to more complex (Howlin, Magiati, & Charman, 2009).

The primary goals of behavioral intervention therapies are to minimize the core ASD features and associated deficits, maximize functional independence and quality of life, and alleviate family distress (Myers & Johnson, 2007). ABA therapies aim at improving "socially significant behaviors." According to Baer, Wolf, and Risley (1968) these behaviors include reading, academics, social skills, communication, and adaptive living skills. Adaptive living skills include both gross and fine motor skills, eating and food preparation, personal self-care (involving toileting and dressing), domestic skills, time and punctuality, money and value, home and community orientation, and work skills.

Applied Behavior Analysis programs involve a number of steps in order to maintain and/or increase both the effectiveness and the efficiency of the intervention. They include:

1. Selecting the interfering behavior or behavioral skill deficit.
2. Identifying goals and objectives, such as learning new skills.
3. Establishing a method to measure target behaviors.
4. Evaluating current levels of performance (baseline).

5. Designing and implementing interventions that teach new skills and/or reduce interfering behaviors.
6. Measuring target behaviors continuously to determine the effectiveness of the intervention.
7. Evaluating the ongoing effectiveness of the intervention, with modifications made as necessary.

In the ABA approach, instructions can be presented in a variety of ways, including free operant procedures (natural language and incidental teaching), discrete trials, etc. Many behavioral researchers advocate that instruction for individuals with autism should be provided in "discrete trial" steps, referred to as the Discrete Trial Training (DTT) approach (Cooper, Heron, & Heward, 2007; Miltenberger, 2008; Smith, 2001).

Discrete Trial Training involves breaking down specific skills into small discrete components or steps that are then taught in a graduated fashion. Often this training takes place during a one-on-one interaction between a child and his or her parent or educator, and reinforcement is used to reward success at each step. Training involves the presentation of a series of trials, each of which comprises the following four components:

1. **Stimulus:** The teacher or therapist presents a brief, distinctive instruction or question (e.g., "Pick up your spoon").
2. **Prompt:** The instruction is followed by a predetermined prompt (e.g., pointing).
3. **Response:** The child responds correctly or incorrectly.
4. **Reinforcement:** The teacher or therapist provides a reward if the response is correct (e.g., "Good job!").

DTT is highly structured, and the choice of stimuli, the criteria for the target response, and the type of reinforcement should be clearly defined before each trial commences. Only the child's correct responses are reinforced; incorrect behaviors are ignored. Despite the frequent use of verbal prompts, teaching is usually conducted with minimal contextual supports in order to encourage the child to develop comprehension of the adult's spoken language.

DTT and ABA are not synonymous; rather DTT represents one of several teaching strategies in the ABA toolbox. Nevertheless, the most frequently cited and recommended intensive behavioral programs continue to focus on DTT as the primary and predominant strategy for teaching children with autism (Roberts & Prior, 2006).

Developmental Intervention

Developmental or relationship-based interventions focus on teaching essential skills (social communication, emotional relationships, and cognitive abilities) that were not learned at the expected age. Developmental interventions are also known as *normalized* interventions (Roberts & Prior, 2006). The two major methods of development intervention are the Developmental Social-Pragmatic Model (DSP) and the Relationship Development Intervention (RDI).

Developmental Social-Pragmatic Model (DSP): The DSP approach goes a step further than contemporary ABA models in its emphasis on the importance of initiation and spontaneity in communication, following the child's focus of attention and motivations, and using more natural activities and events as contexts to support the development of the child's communication abilities (Roberts & Prior, 2006).

Put simply, DSP interventions aim at increasing the adult's responsiveness to the child and establishing balanced turns between the child and the adult (Mahoney & Powell, 1988). According to Ingersoll et al. (2012), support for DSP intervention has been largely drawn from research on both typically developing children and children with autism that demonstrates an association between the parent's level of responsiveness and the child's joint attention and language development over time. Over the past few years, several controlled studies have evaluated the effectiveness of this approach (Green et al., 2010; Ingersoll, Dvortcsak, Whalen, & Sikora, 2005; Kasari, Gulsrud, Wong, Kwon, & Locke, 2010). Results from these studies show that there is strong evidence DSP interventions can increase parent responsiveness and joint engagement between the parent and child; however, there is only limited support for the efficacy of DSP interventions for increasing language and other social communication skills in children with autism (Ingersoll et al., 2012).

Relationship Development Intervention: Relationship development approaches are cognitive-developmental parent-training programs that focus on enhancing emotional and social interactions (Gutstein, Burgess, & Montfort, 2007). RDI therapies aim at remediating biologically based processing capacities, such as auditory processing and language, motor planning and sequencing, sensory modulation, and visual-spatial processing (Roberts & Prior, 2006).

In this method parents attend 6 days of intensive workshops in the theory, principles, and components of RDI, followed by planning and regular weekly or biweekly consultation meetings with a certified RDI consultant. RDI workshops train parents on responding to their children's needs in challenging and increasingly unpredictable settings in more flexible, thoughtful ways. Parents and children participate in intensive re-evaluation approximately every 6 months (Gutstein, Burgess, & Montfort, 2007).

Gutstein, Burgess, and Montfort (2007) conducted an evaluation of the relationship development intervention program where they reviewed the progress of 16 children who participated in an RDI. Their study demonstrated gains in relation to flexibility in learning new skills and educational placement (functioning in mainstream classes without an aide compared to special education classrooms). Follow-up results demonstrated that these children retained their improvement for an average of over 3 years.

Combined Interventions

Combined interventions are programs that combine elements of the behavioral interventions and developmental models discussed earlier, but are mainly based on a specific approach. Combined interventions place great importance on managing the environment to facilitate learning and development (Roberts & Prior, 2006).

The Social Communication/Emotional Regulation/Transactional Support (SCERTS) program is an example of a developmentally based combined intervention model. The SCERTS model focuses on each child's developmental strengths and natural motivations to address primary deficits affecting them. According to Wetherby and Prizant (2000) the developmental challenges experienced by children with autism do not occur in an isolated manner, and therefore should be treated by considering them as a whole rather than the sum of the parts.

The Treatment and Education of Autistic and Communication-related Handicapped Children (TEACCH) method is a "whole life" approach, and focuses on structuring the environment to facilitate skill development and independence. To help children understand each exercise, clear physical and visual supports are established to promote meaning and independence. The principles of the TEACCH model include understanding the culture of autism, using an individualized one-to-one and family-centered plan, organizing the physical environment, putting forth a predictable sequence of tasks, and employing visually structured activities (Cervera, Romero, Mas, & Delgado, 2011).

A number of empirical studies have been conducted on the effectiveness of the TEACCH method. Schopler, Mesibov and Baker (1982) evaluated the outcomes of a study on 647 students between 2 to 26 years old that graduated from or were currently enrolled in the TEACCH program. Results indicated that the subjects who were most involved in the program saw the most improvements. Three additional follow-up studies (Lord & Schopler, 1989; Venter, Lord, & Schopler, 1992; Lord, 1995) reviewed gains from the TEACCH method. In each of these studies, substantial increases in IQ scores were reported. Unfortunately, these studies did not use control groups to account for other factors, such as maturation, which may have contributed to the outcomes. However, Ozonoff and Cathcart (1998) conducted a study of the effectiveness of a TEACCH home-based program that featured a control group and found that the children in the treatment group made significant progress and demonstrated overall improvement that was three to four times greater than that of the control group. Panerai, Ferrante, and Zingale (2002) performed another controlled study evaluating the TEACCH method for two groups of eight children with autism and severe intellectual disability. Results from their study indicated that the group of children who received TEACCH made significantly greater gains than those in the control group. However, their study involved a small sample, and further studies involving larger groups of children need to be performed in order to evaluate the effectiveness of the program fully (Roberts & Prior, 2006).

Learning Experiences and Alternate Program for Preschoolers and their Parents (LEAP) is a combined intervention approach where small groups of children with autism are taught alongside a small number of neurotypical children. According to Strain and Hoyson (2000), the program consists of 15 hours per week of classroom instruction provided by a teacher and an assistant, who implement the program with 10 typically developing children and 3-4 children with autism. A full-time speech therapist and contracted occupational and physical therapists are also available to work with the children in specially arranged classrooms designed to support child-directed exercises. The LEAP curriculum is designed to expose autistic children to typical preschool activities and adapt the curriculum to the needs of the autistic children only when necessary.

A longitudinal study of six individuals with autism over the course of 18 years by Strain and Hoyson (2000) found that the use of the LEAP model resulted in increases in social skills and appropriate behaviors that were sustained over time. A larger longitudinal study by Strain and Bovey (2011) was conducted to examine the broader effects of the LEAP program. In their research, they studied 77 students with autism, divided to an experimental group and a control group. After 2 years, experimental class children were found to have made statically significant improvements over the control group on measures of cognitive, language, social, problem behavior, and autism symptoms. The analysis of child outcomes showed that improvements were not correlated with initial baseline performance, with the lead teacher's level of experience or prior training, or with family socioeconomic status, meaning that the gains were not attributable to the children's prior knowledge, teacher's expertise, or family's socioeconomic status.

There are multiple educational intervention models that can be grouped into behavioral, developmental, or combined interventions. Among all the three models, the behavioral interventions have shown the most benefits (Matson et al., 2012; Cervera et al., 2011), although the developmental and combined interventions approaches can also improve the social and relation skills of the child with ASD. Discrete Trial Training is a behavorial approach that has been selected for the purpose of this study among the many different interevntion models due to its compatibility with computer-assisted programs. Because DTT involves breaking down specific skills into small discrete steps, it can be easily implemented in a computer-assisted setting to teach skills in a graduated fashion. As a result, this project focuses on delivering multi-step training using Discrete Trial Training.

Efficacy of Educational Interventions

Several empirical research projects have been carried out to assess the effectiveness of educational interventions. Lovaas was one of the earliest researchers who demonstrated the effectiveness of behavioral interventions based on Applied Behavior Analysis for children with autism. In his study, Lovaas reported that preschool children involved in one-on-one therapy for 40 or more hours a week and over at least 2 years showed major gains in IQ (up to 30 points) and significantly improved rates of integration in mainstream school; in fact, 47% of the children attained normal intellectual and educational functioning (Lovaas, 1987). A subsequent follow-up by McEachin, Smith, and Lovaas (1993) showed that these gains were maintained until early adolescence.

According to Reichow (2012), since 2009, five meta-analyses of Applied Behavior Analysis for young children with ASDs have been published in peer-reviewed journals (Makrygianni & Reed, 2010; Eldevik et al., 2009; Reichow & Wolery, 2009; Spreckley & Boyd, 2009; Virués-Ortega, 2010). Four of the five meta-analyses (Eldevik et al., 2009; Makrygianni & Reed, 2010; Reichow & Wolery, 2009; Virués-Ortega, 2010) concluded that behavioral interventions are an effective intervention strategy for many autistic children, while only one study (Spreckley & Boyd, 2009) reported that behavioral interventions were not superior to standard care.

Makrygianni and Reed (2010) reviewed 14 studies that focused on the effectiveness of behavioral intervention programs for children with autism spectrum disorders. Their inclusion criteria required that the reviewed studies had evaluated comprehensive treatment using ABA principles, were based on methods and research findings of behavior analysis, included children with ASD, involved children who averaged 54-months-old or younger, provided assessments of the children's intellectual, language, and/or adaptive behavior, provided comparable results for at least one developmental aspect, and had moderate to high methodological quality. Cumulative results from their review showed that behavioral early intervention programs are effective, and that they can improve the intellectual, language, and adaptive functioning of children with ASD. The reviewers concluded that behavioral programs are effective in improving children's treatment gains. Factors that they found important for the efficacy of the behavioral interventions were the intensity and the duration of the program, the age of the children, the adaptive behavioral abilities of the children, and parent training.

Eldevik et al. (2009) conducted a systematic literature review of studies reporting effects of behavioral interventions for preschool children. In their review, they identified 34 studies, 9 of which were controlled designs that included either a comparison or a control group. They focused on studies that included assessments of intelligence and/or adaptive behavior measures. Their review concluded that in the absence of other interventions with established efficacy, early intensive behavioral intervention should be an intervention of choice for children with autism.

Howlin, Magiati, and Charman (2009) conducted a systematic review of controlled studies of early behavioral interventions for preschool children with autism. Eleven studies, including two randomized controlled trials, met the inclusion criteria and were selected for review. At the group level, they found significant group differences in IQ in 9 of the 11 studies, where ABA was reported to associate with improved outcomes, primarily measured by IQ. At the individual level, however, studies reported considerably variable outcomes, with some evidence that initial IQ was related to progress. As a result, their review suggests behavioral interventions being effective for some but not all preschool children with autism.

Spreckley and Boyd (2009) performed a study to review the effectiveness of applied behavior intervention programs for preschool children with autism spectrum disorder in their cognitive, adaptive behavior, and language development. They reviewed 13 studies that met their inclusion criteria, 4 of which were randomized or quasi-randomized clinical trials. Meta-analysis of these 4 studies concluded that ABI did not result in significant improvement in cognitive, language, or adaptive behavioral outcomes compared with standard care. However, their study had several limitations, such as high variability in the included studies, poor homogeneity, and lack of strict inclusion and exclusion criteria.

Eikeseth, Smith, Jahr, and Eldevik (2007) studied the effects of ABA therapy for children with autism who began treatment at a mean age of 5.5 years compared to an eclectic treatment group. (In eclectic treatment, instead of choosing one particular approach, elements from a range of therapeutic techniques are employed.) Measures in this study included IQ, language functioning, adaptive functioning, maladaptive behavior, and socio-emotional functioning. Results from their study showed that the ABA treatment group scored significantly higher compared to the eclectic treatment group in intelligence, language, adaptive functioning, maladaptive functioning, and socio-emotional assessments of social and aggression measures. These findings suggest that ABA treatment is effective for children with autism.

In a similar study, Howard, Sparkman, Cohen, and Stanislaw (2005) compared the effects of three different treatment approaches in children with autism. A group of 29 children received 25 to 40 hours per week of one-to-one ABA treatment. A comparison group of 16 children received 30 hours per week of one-to-one or two-to-one eclectic intervention in public special education classrooms. A second comparison group of 16 children received 15 hours per week of public school early intervention services in small groups. Measures included IQ, language functioning, and adaptive functioning. Results from this study showed that the ABA treatment group scored significantly higher compared to the two control groups on all the measures.

Several other research studies have shown similar results, demonstrating that children who received ABA made significantly more gains than control-group children on standardized measures of IQ, language, and adaptive functioning, demonstrating the effectiveness of ABA-based treatments for children with autism. However, most of these studies are characterized by some methodological limitations, including their small sample size and the lack of a comparison group, matched groups, or random assignment of the children. Nevertheless, according to Matson et al. (2012), ABA is the most effective method available to treat autism until other procedures and methods are developed and proven to be superior by direct comparisons or, at minimum, by the publication of multiple studies by different research teams.

In summary, autism therapies can be grouped into two major categories: biologically based interventions and educational interventions. Educational interventions can be described as behavioral, developmental, or combined interventions. Discrete Trial Training is the predominant behavioral strategy currently being used for teaching children with autism, and it has been selected for the purpose of this project due to its known efficacy and its compatibility with computer-assisted programs. In the next chapter, the creation of a customizable DTT application for use on iOS devices, which is the central goal of this project, will be described.

Chapter 3. Wave Mobile Platform

The mobile application developed in this study is called Wave. It is a mobile platform for teaching Discrete Trial Training exercises and provides customizable programs to support the specific learning needs of children with autism. The mobile platform is currently a working prototype without a database to store information; therefore, the available programs in this prototype were built and executed statically, not generated dynamically from a database. The focus of this project is on the user interface, evaluating its usability and its interaction design for building and delivering DTT training sessions.

The interface includes four sections that provide easy access to the main aspects of the application: Dashboard, Programs, Students, and Library. **Dashboard** provides a quick glance at students' progress updates. **Programs** provides a list of the available exercises, categorized into groups. **Students** includes a list of the enrolled students, who can be organized into classes. **Library** contains all the pictures, videos, animations, and multimedia stimuli that can be incorporated into the programs.

The Dashboard area is designed to provide a quick overview of students' progress (Figure 3.1). It allows teachers to monitor their students' recently completed programs. Students' names are shown in a high-contrast bar, which groups their information and visually separates them from each other. The number of programs assigned to the student is provided in the same high-contrast bar to the right. Each assigned program is listed under the student's name, and each includes the program name, target skills, assigned date, and completion details. The completion details include the completion status, the completion time for completed programs or completion percentage for incomplete programs, and the percentage of accuracy achieved by the student. Providing data on both accuracy and completion time (the time to complete the program from start to finish) is helpful for teachers in determining student's training performance. Also on the Dashboard, in the top right corner, is a User Account button; this lets teachers sign in and out of their accounts and allows a teacher to set the app to Student Mode. Student Mode restricts user access to a list of the assigned programs that are available to the student. This feature helps by displaying only relevant information to the student; it also prevents students from altering other sections of the application.

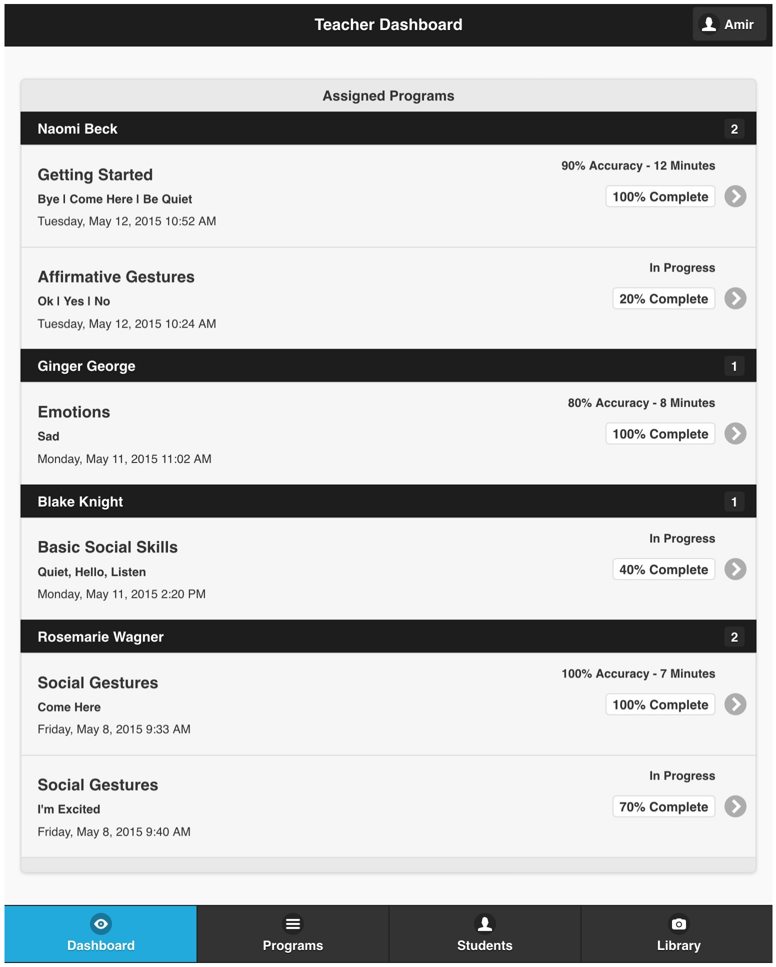

Figure 3.1. Dashboard

The Programs section is designed to provide easy access to the available programs (Figure 3.2). Programs can be grouped into categories under the left panel. Categories can be moved higher or lower in the list. Each program listing includes a picture of the target stimuli, the program name, the program type (mass trial, mixed, or custom), the target skills, and the number of trials in the program. Tapping on a program listing opens a popup action window from which the teacher can start the program, assign it to an enrolled student, or modify it. The Programs section also includes a filterable search function that aids in quickly locating programs.

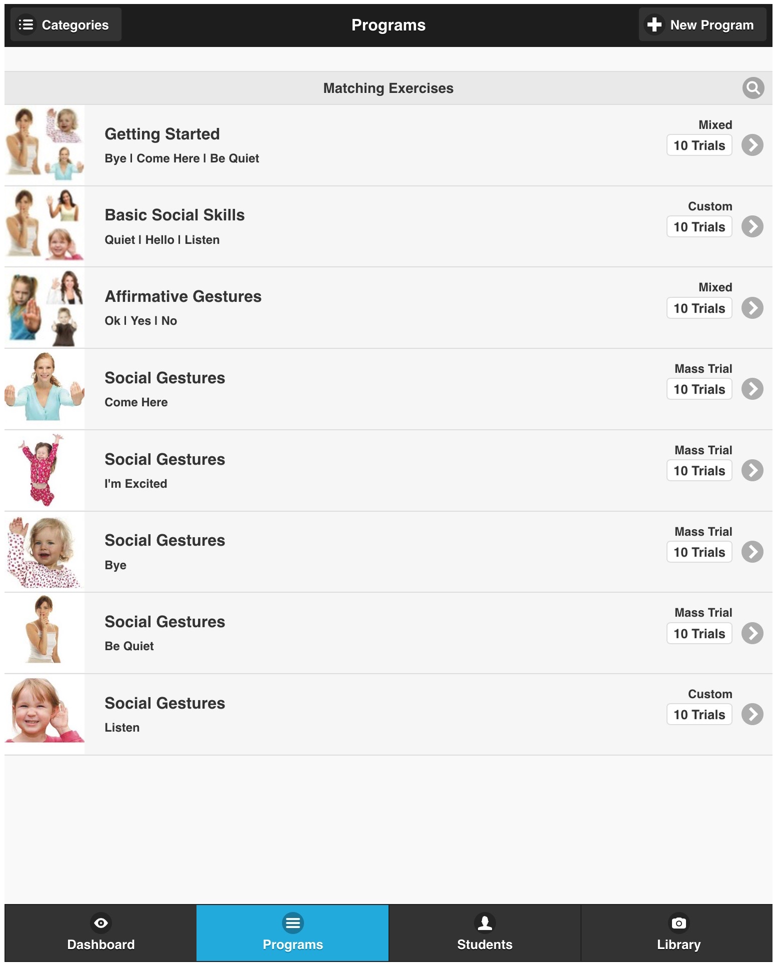

Figure 3.2. Programs

Note: Pictures courtesy of babysignlanguage.com

In addition to these features, the Program section provides a New Program button in the top right corner, which allows the teacher to build a new program in one of the three types: mass trials, mixed trials, and build-your-own (custom). The mass trials type focuses on only one target at a time throughout the program, while mixed trials allows the teacher to add programs with multiple targets. Upon completion of the selections, the application will place the target skills into trials and randomize their appearance in the created mixed trials program. The build-your-own type allows teachers to customize each trial within the program. All program types include the ability to choose the number of trials, the required completion accuracy, and the random rotation method used to select the stimuli (e.g., random, Latin Square, Latin Hypercube, Orthogonal sampling), and to select the target skill(s) from the Library (Figure 3.3).

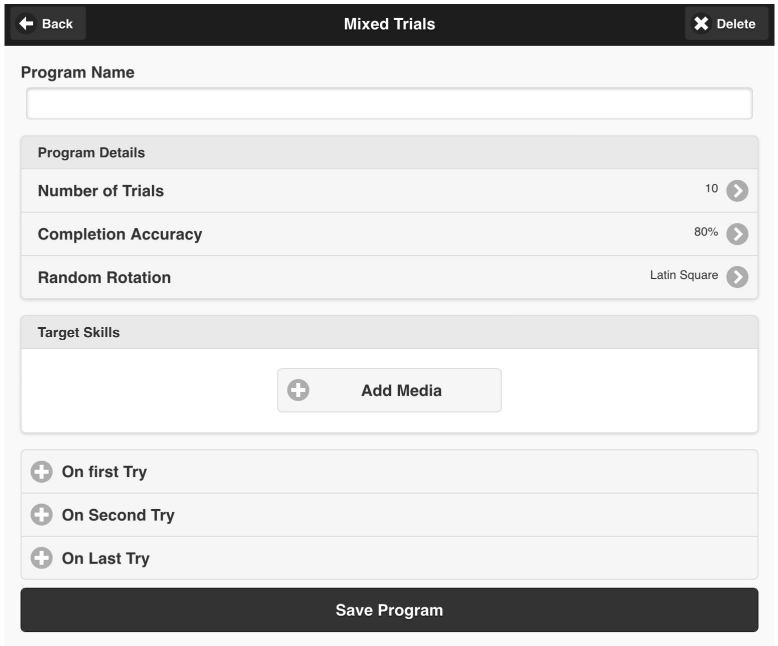

Figure 3.3. Mixed trials

The program creation interface also allows teachers to customize the verbal instruction, reinforcement, and prompt for the first, second, and last try depending on the student's needs (Figure 3.4). For instance, a teacher can provide a more favorable reinforcement on the initial try and have the field size reduced to fewer stimuli upon incorrect answers. The teacher can set the program to provide a hint to the correct answer by glowing the edges or bouncing the correct answer on the second try. Finally, the teacher can choose to display the correct answer on the last try, avoiding any reinforcement. These customization options on each try are an important part of the DTT method to support autistic children's learning needs.

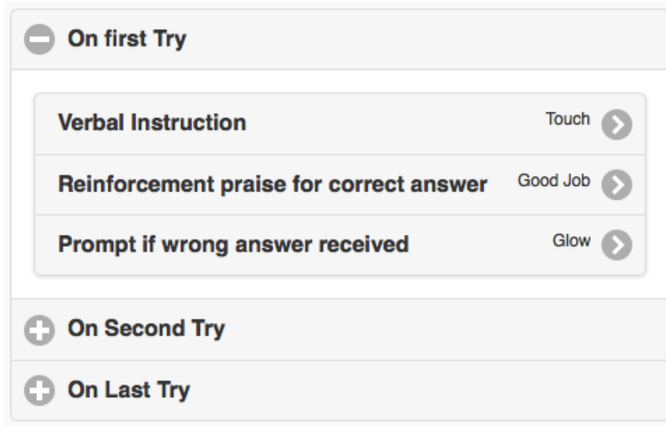

Figure 3.4. On first try customizations

In order to provide maximum customization to meet the needs of autistic students, the interface's custom (build-your-own) programs provide the teacher with the option of creating every trial within a program manually in order to allow more control over how an exercise is presented. The teacher can add media to any trial and order those items under the target skills section (Figure 3.5). Several different designs, including a left flyover panel and a split view, were tested for displaying trials and allowing access to modifying them. Since the program details and the first, second, and last try configurations apply to the entire program, in the

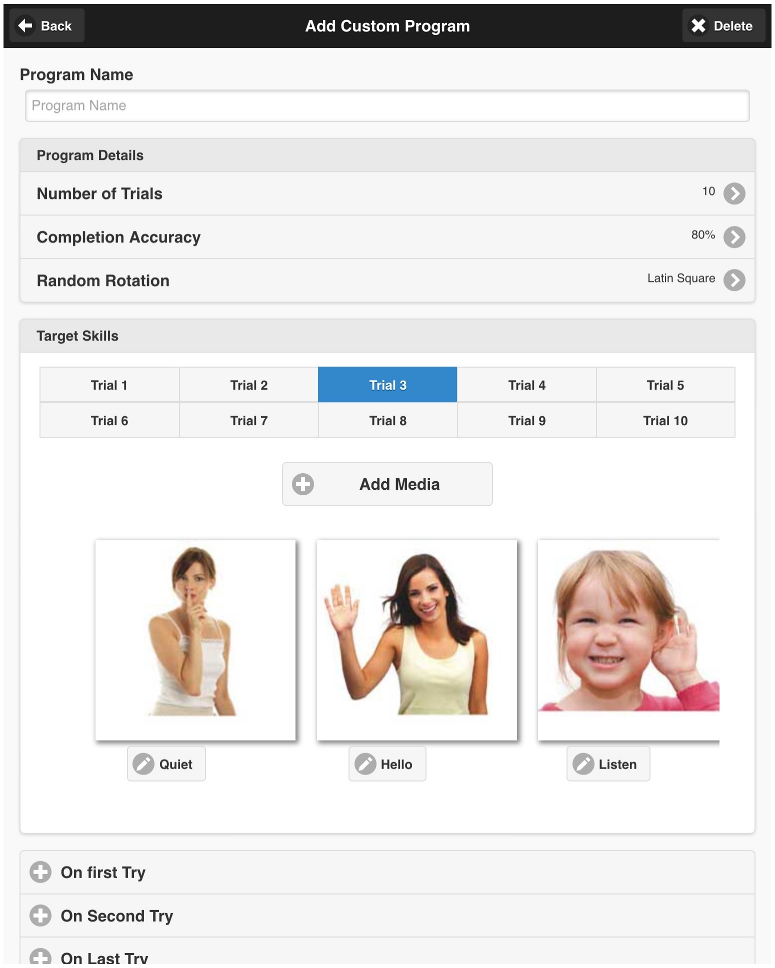

Figure 3.5. Build your own program

Note. Pictures courtesy of babysignlanguage.com

previous designs that information was included on a separate page. However, navigating between the settings for a program and its trials presented an interaction design problem. In the new design, trials are presented in tabs on the same screen as the configuration options for the entire program. This design remains consistent across mass trials, mixed trials, and custom program pages, and therefore helps the user to understand the information architecture of the application more easily.

The Students section is similar in design to the Programs section. It lists all the enrolled students and allows the teacher to group them into categories (classes) in the left panel. A filterable search option is available to help the teacher find an individual student quickly. The

New Student button in the top right corner allows new students to be added to the system. Tapping on a student's name opens the Student Profile page (Figure 3.6), which includes the

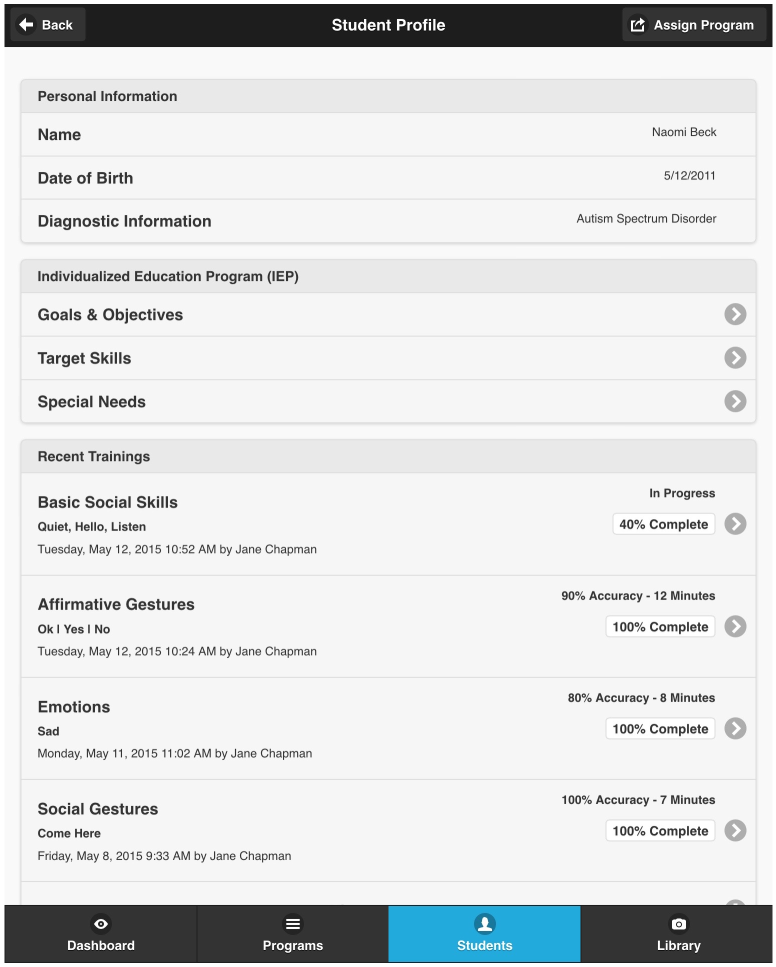

Figure 3.6. Student profile

student's personal information (name, date of birth, and diagnosis), the details of the student's Individualized Education Program (IEP), and the student's training history on the platform.

The Library section includes pictures, animations, videos, and other multimedia items that are laid out in a gallery format (Figure 3.7). These items can be grouped into categories in the left panel, similar to the Programs and Students sections. Tapping on an item displays an edit screen that allows users to edit the item and/or create multiple versions of the same item. Each version can have its own recorded instructions to accommodate different children's needs. An Add More button in the top right corner allows the addition of media from the mobile device's memory, as well as taking pictures and making recordings using the device's camera. Downloadable packages of media can also be made available.

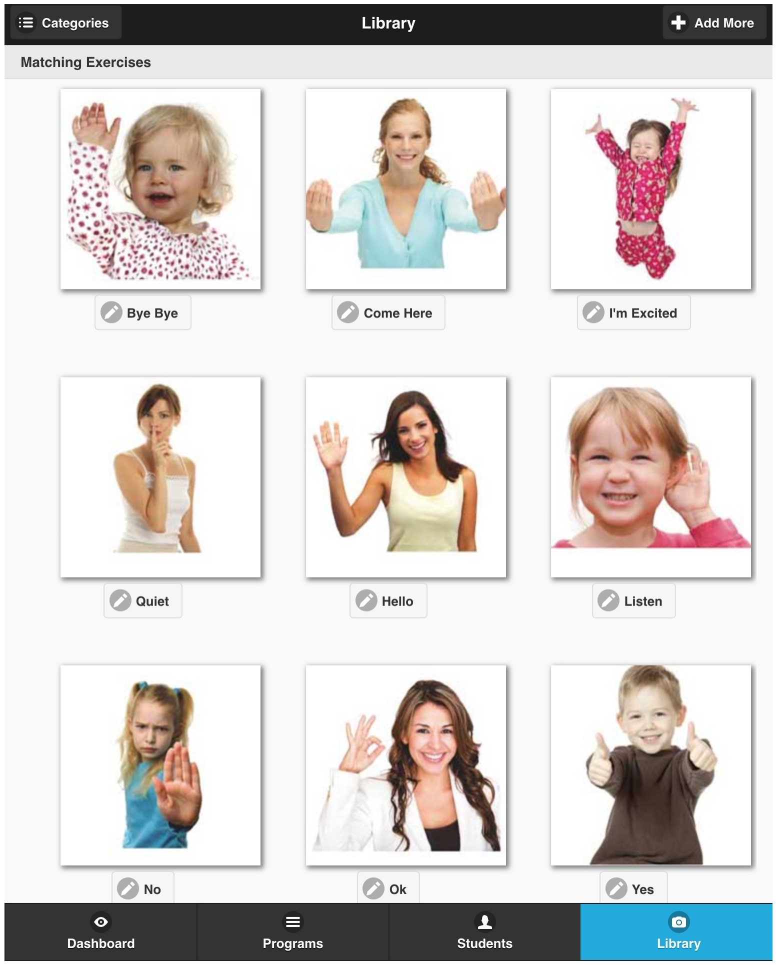

Figure 3.7. Library

Note. Pictures courtesy of babysignlanguage.com

Several design factors were incorporated in the Wave application to help it meet the needs of educators. It covers a wide range of Discrete Trial Training exercises, including matching exercises, imitation skills, and natural environment trainings that can be combined to effectively teach the student. It allows for the customization of each trial in a program, as well as for modifications to the verbal instruction, reinforcement, and prompting in order to support each individual's training needs. It also provides automated programs to assist the teacher in saving time when building programs. The user studies of this platform were carried out with a focus on the interaction design, with the intention of improving the user experience. The result is an application that is designed to be user-friendly and to allow therapists and trainers create programs easily. The application code is included on a CD enclosed with this dissertation; it can also be viewed online at the following address: https://github.com/achamsaz/Wave

Chapter 4: Methodology

This project was implemented in two stages. In the first stage, an interactive prototype for two devices (iPhone and iPad) was developed using Axure. The Axure prototype was tested with four users to assess usability and to identify areas in need of improvement. In the second stage, a mobile application prototype was developed using jQuery Mobile and tested with two pilot testers and twelve users. This chapter explains the procedures for developing the original prototype and testing it, as well as the procedures involved in the development of the second prototype mobile application and its user tests.

First Prototype Development (Axure)

In the first stage, Axure RP Pro 6.5 was used to develop an interactive prototype. The focus of this prototype was on the usability of the user interface for building programs with the app. Two versions of the prototype were actually developed—one for iPhone and one for iPad—in order to explore the interaction design considerations related to a smaller mobile screen size versus a larger tablet screen size. The iPhone version incorporated a drill-down interface, while the iPad version used a split-view design. Both interfaces included four tabbed navigation sections: Programs, Students, Objects, and Settings.

This first prototype included a sample program consisting of 10 trials. Users were able to add or remove pictures from the trials and set the correct answer in each trial. The prototype also allowed users to adjust the verbal instruction, reinforcement, and prompt. More specific details about the user interface of the prototype are described in Chapter 5 in connection with the results of the first prototype user study and the influence of those results on the design of the second prototype.

First Prototype User Testing

Four user testing sessions were conducted using the first prototype. The user testing sessions were aimed at improving the user experience related to creating programs and modifying them. The interviews with the participants were recorded, and the findings were documented to aid in improving the prototype design. Results from the first prototype user tests were used to develop the second prototype of the application. The results of the tests are described in Chapter 5.

Participants

A convenience sample was used for evaluating the prototypes. Four users (one male and three females) who already owned an iPhone and/or iPad device participated in the user tests. These users were screened to be familiar with the iPhone/iPad interfaces in order to eliminate the ambiguity factor related to understanding the standard interface conventions, such as navigational tabs at the bottom, split views, and fly-over left panels.

Procedure

At the beginning of the test, participants were provided with an overview of the user study. The overview included the goal of the user study and discussed the procedures for conducting the interview. The prototype interview script is provided in Appendix A.

To minimize the "order effect," two of the users were asked to start with the iPhone interface, while the other two users were instructed to start with the iPad interface, so that their familiarity with the tasks would not affect their judgment of the interface and its ease of use.

Since the application is capable of delivering various types of training using the DTT method, in order to keep the user tests simpler at this phase, exercises relating to nonverbal social tasks were not used for testing the interface design. Instead, a more general coin-matching exercise was employed using the same procedures.

HTML-generated prototypes were uploaded to the AxShare website for online access. This allowed for the prototypes to be tested by using the device's web browser. By choosing "Add to Home Screen" in the mobile web browser, a link to the prototype was added to the device's home screen so that the prototype could be accessed in similar way to a stand-alone app. The browser's address bar was set to "hidden" in order to allow the prototype app to run in full-screen mode for best performance.

Task Scenarios

The user tests included three task scenarios and a follow-up question for each device type (see Appendix B). After completing these on one device type, users continued to the next device type and carried out the same task scenarios on that device's interface. The following task scenarios were used:

Activity 1: You have already created a program called "Money Concepts." Please go to that program and run it for the child to play.

Activity 2: You are interested in changing an item on the first trial of the Money Concepts program. There is a Canadian nickel among the trial objects that you would like to change with an American nickel from your objects library. How would you change it?

Activity 3: Children can answer a question up to three times in each trial. After each error, a prompt will be provided as a clue to the correct answer (i.e., shaking the correct answer and zooming in to it). These prompts and the instruction for each of the three tries can be customized. Where would you go to adjust those customizations?

After the activities were completed, a follow-up question was asked: "What do you think about the interface? Do you have any general comments?" The user was then instructed to change to the other device and complete the same activity tasks. Finally, the user was asked these follow-up questions: "Which interface did you like better and why? What would make this app better? Do you have any further comments?"

Second Prototype Development (jQuery Mobile App)

In the second stage of the project, jQuery Mobile platform version 1.4.5 was used for developing the prototype mobile application. jQuery Mobile is a touch-optimized mobile framework developed by the jQuery project team based on HTML5. For the purposes of the creating the Wave app, jQuery Mobile was determined to have various advantages. Because it is a web-based, cross-platform framework, it is compatible with various mobile devices, operating systems, and screen resolutions. In addition, both future phones and older browsers are supported, due to jQuery's progressive enhancement. Mobile web technology allows the app to run on any smartphone or tablet, as well as on desktop computers, eliminating the need for installing applications on specific devices. Using web-based technology also allows for storing data in the cloud, so teaching programs can be shared, assigned, and accessed on different devices at different locations. The only disadvantage to this approach is that using the app will require an active Internet connection.

Since jQuery Mobile is optimized for various screen sizes, the need to create two different interfaces to support both the iPhone and iPad was eliminated. As a result, the findings from the first prototype user tests could be incorporated into a single interface design that was compatible with both smartphones and tablets. Another benefit, from a design standpoint, is that jQuery Mobile incorporates page transitions powered by AJAX navigation, which allows seamless navigation among pages. It also includes pre-made themes and widgets that can be added by referencing custom classes, and it supports a theming framework that allows easy creation of custom themes. These characteristics make jQuery Mobile an easy-to-use but powerful framework for web-based mobile development, ideal for the creation of the second prototype.

A single page design was adopted for developing the application. jQuery Mobile allows creating multiple pages in a single HTML file by separating each page with a unique id and using the href attribute to link between them in the form of <div data-role="page" id="pageone">Page Content</div>. The single page design allowed a faster development cycle by eliminating the need for developing across several separate pages.

The second Wave prototype application included 31 pages and about 2000 lines of HTML code. Each page was divided into several components, including an optional left panel for categories, a header, content, notification popups, and a static footer. A number of design changes were incorporated into the second prototype based on the results of the first prototype user tests; consequently, the design specifics of the second prototype will be discussed in the Results (Chapter 5). In order to more realistically test the application in the context in which it will be used by educators, the statically created programs, trials, and objects in the second prototype were based on non-verbal gesture training for children with ASD.

From a functional standpoint, the second prototype was designed to allow using media related to the target skills to create programs that can be assigned to students whose progress is then displayed on the Dashboard (Figure 4.1). Media is added to the Library from the device photo library, recorded using the device camera, or downloaded from available packages. Programs can be built in three ways using these media: mass trials target one skill at a time; mixed trials allow the selection of multiple stimuli, and build-your-own (custom) allows teachers to customize each trial in the program. These programs can then be assigned to students. As students complete the programs, their progress is logged on the Dashboard, and an overview of their training history over time becomes available in their Student Profile.

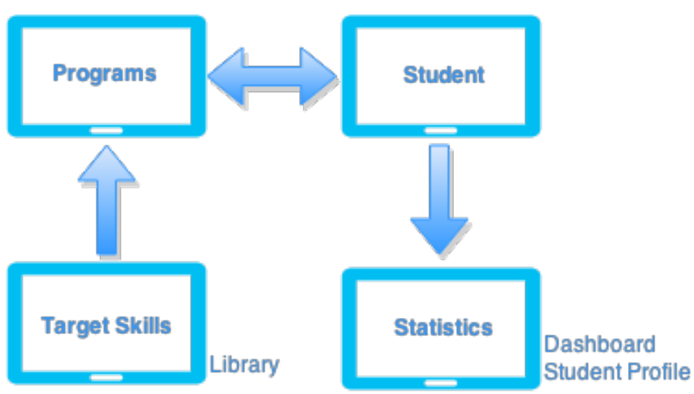

Figure 4.1. Functional components of the application

Second Prototype User Testing

Two pilot tests and twelve user tests on the second prototype were conducted, using the app on an iPad. The two pilot users were chosen for convenience and for their experience in user interface design and usability testing. For the twelve user tests, six Discrete Trial Training experts—five from the Kennedy Krieger Institute and one from the Hussman Institute for Autism—participated in order to give expert feedback on the training method. The other six participants were chosen for their knowledge of user interface design. Interviews were recorded and observations made during the user tests were documented. Results from these tests are provided and discussed in chapter 5.

Participants

The two pilot users were fellow students. In the user study, 12 subjects (8 females and 4 males) participated. Of these 12 subjects, 6 participants had experience with the Discrete Trial Training method, 5 had worked with children with special needs, 4 had provided training to students with autism spectrum disorder, and 1 had a child diagnosed with ASD. Five of the participants had previously used a tablet (e.g., iPad) for teaching purposes. Charts depicting demographic data about the user study participants are provided in Appendix C.

Procedure

The pilot testers performed the tasks (described in the next section) and gave feedback, but did not participate in any of the other procedures, including recording of the test.

User tests were conducted in the form of user interviews. Users were asked to sign a consent form that explained the study and their right to withdraw from the study at any time; by signing, they also agreed to the recording of their interview session for the purposes of the study. A copy of this consent form is provided in Appendix D. Users were then presented with information on the background of the method and the purpose of the user study. Different aspects of the application were discussed in order to provide subjects with an overview of the user test. The interview script is provided in Appendix E.

User interaction with the iPad during the user tests was recorded using a GoPro Hero3 camera that was connected to a Jaws Flex Clamp mount. This mount directly grips the top of an iPad, allowing for the camera to record user interaction from above (Figure 4.2). The camera was set to rotate the video captures to remediate for the recording direction.

Figure 4.2. User study set up

Task Scenarios

Four task scenarios were employed in developing the second prototype user study (see Appendix F). The main functions of the application and four major goals related to them were identified. They included playing an exercise, building an exercise, interacting with the Students section, and interacting with the Library section. These goals were used as the basis for developing relevant tasks. Tasks were then rephrased as scenarios to add context and provide participants with an explanation for each task. During the tests, tasks were referred to as "activities" to avoid making the participants feel they were being tested on their performance. The following task scenarios were used in the second prototype user study:

Activity 1: You have already created an exercise called "Getting Started" to teach three nonverbal gestures: *Bye Bye*, *Come Here*, and *Be Quiet*. Please go ahead and play that exercise.

Activity 2: You are interested in building an exercise to teach *Be Quiet*, *Hello*, and *Listen*, where *Be Quiet* is presented on the first trial, *Be Quiet* and *Hello* are presented on the second trial, and all three stimuli are presented on the third trial.

Activity 3: Naomi Beck is one of the children you are working with. You have assigned a few exercises for her to complete. How would you check her progress and her training history?

Activity 4: You would like to use your own voice for the instruction that is played for the *Be Quiet* stimulus. How would you do that?

Follow-up: What do you think about the interface? Do you have any suggestions for improving the app?

The findings from the prototype user tests are described in the next chapter (Chapter 5), including a more detailed description of the user interfaces in connection with those findings. In addition, Chapter 5 describes how the outcome of the user tests affected the development of the application; it also documents which findings were incorporated to improve the user experience and which items were discarded or recorded for future implementation.

Chapter 5: Results

The purpose of this project was to create a mobile application that will allow educators to create customized training programs based on the Discrete Trial Training method. The design of the application was intended meet the following goals: helping educators to save time by being able to build exercises once and reuse them over time; enabling educators to adjust the programs to meet each student's needs and to monitor student progress; and allowing parents to work on the same exercises with their children.

The audience group for the application was considered to be the educators who plan and design intervention programs, the high-functioning autistic children who participate those programs, and the parents and caregivers who assist children in carrying out the tasks in those programs.

This chapter describes the interactive prototypes in further detail and examines the results of the user tests that influenced the application development and different aspects of the mobile interface. A preliminary interactive prototype in two versions (iPhone and iPad) was created first in order to test the mobile delivery method. Four user tests were conducted on that prototype to identify requirements for designing the application, and the findings from those tests were used in developing the second prototype of the application. Two pilot tests and twelve user tests were conducted using the second prototype app on an iPad. These user tests resulted in overall improvements to the application.

First Interactive Prototypes (Axure)

Two versions of the first prototype (included on a CD enclosed with this dissertation) were created in order to test the effects of screen size on the interface. The iPad interface involved a split view design (Figure 5.1), where trials were listed in the left panel and the content of the active trial was displayed in the right panel. Selecting each trial in the left panel would refresh the right panel, allowing users to remain within the same interface. The iPhone interface

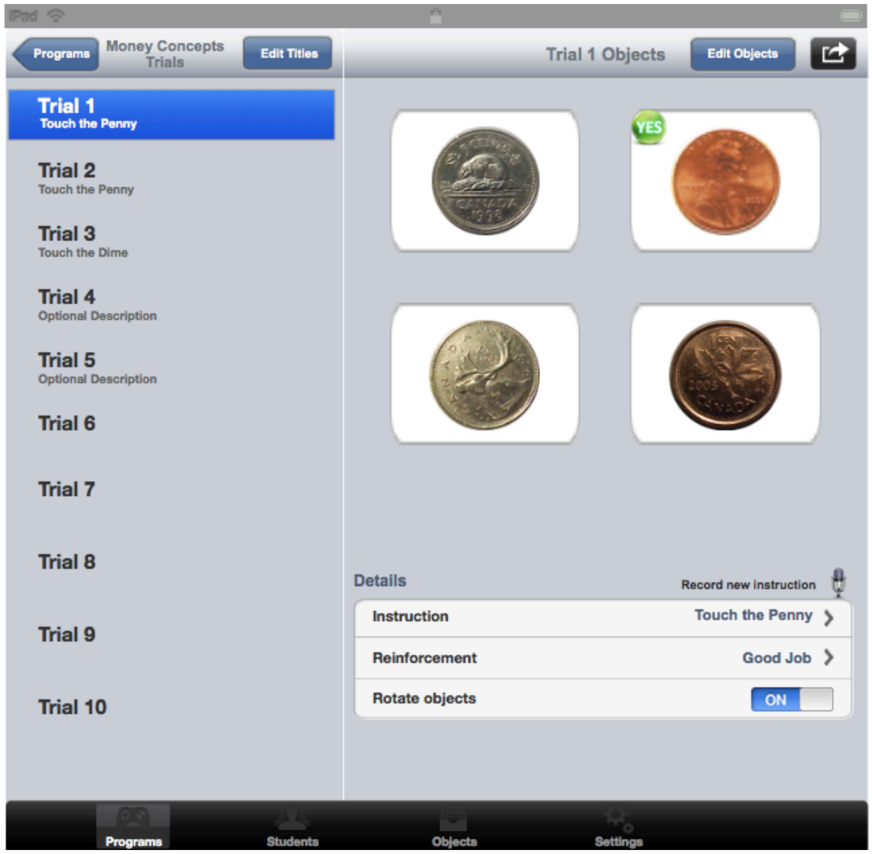

Figure 5.1. iPad interface

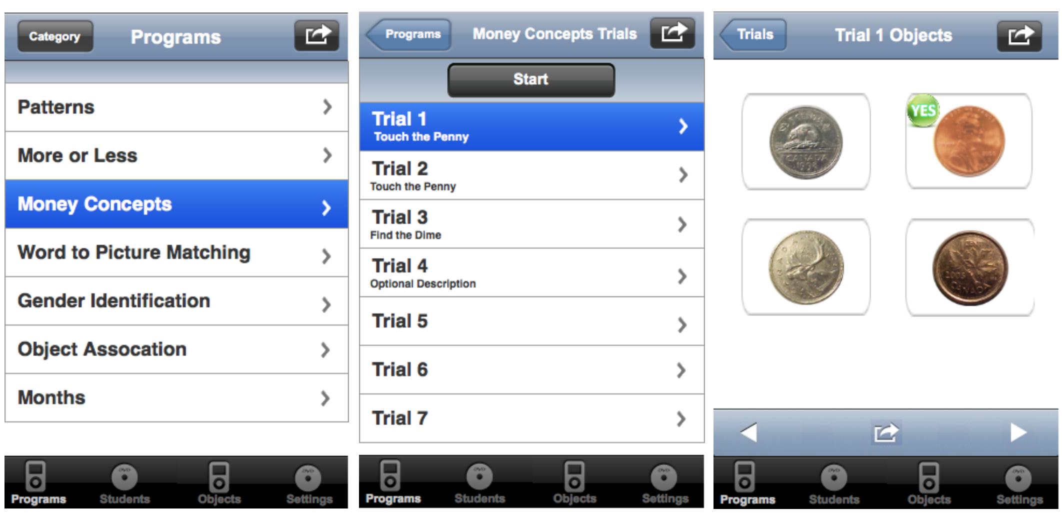

Figure 5.2. iPhone interface

incorporated a drill-down interface design (Figure 5.2), where each screen was displayed in a separate window. Users would drill-down in each step and could return back to the previous screen by selecting the back button. The back button displayed the title of the previous screen to aid users in orienting within their drill-down navigation.

Both interfaces included four tabbed sections: Programs, Students, Objects, and Settings. Programs included a list of available programs, Students included a list of enrolled students, Objects contained the media items that were used in Programs, and Settings enabled users to customize sensory information such as sound and vibration.

User Study Findings

Based on the participants' feedback, the changes described in this section were implemented. In the case of each change made, the findings of the user study are discussed, along with solutions for addressing each issue. Revisions to the prototype were made while user testing progressed. Note that the findings in this section are not grouped according to iPad or iPhone platforms, since most of the issues addressed both versions. In those instances where different solutions were carried out based on the device platform, the solution is discussed according to its platform.

Rename "Stamps" to "Objects": The initial iteration of the first prototype called the stimuli media "Stamps." The idea behind using "Stamps" instead of "Flashcards" was to make the title distinctive from existing applications. However, prototype user testing showed that this title was not understandable to the audience, so "Objects" was used instead. (As the study progressed, "Objects" was changed to "Library" in order to emphasize that it was a collection of items.)

Differentiate between selectable items and Library items: During the user test, it was observed that one user who hit the Add button and was presented with items from the Library to add to the trial became confused about the connection between the presented interface (the list of available items to add) and the actual library interface (where items are listed, can be organized, removed, and more items downloaded/added etc.). Consequently, the interface architecture was modified to differentiate between the items currently being selected and the Library section. In addition, the Add From Objects Library window was modified to roll up from the bottom of the screen to provide a visual cue that the new screen for selecting Library items is a subset of the main screen.

Use the same discriminative stimuli (SD), reinforcement, and prompting settings across a program: Initially, the interface included three prompting configurations for each trial. While discussing this with a therapist, she suggested using the same configuration for all the trials in each program. She explained that the same instructions should be provided in each try. As a result, these configurations were moved to the Settings section.

Change the correct answer icon: Originally, the interface included a gray checkmark that changed to green when the user selected an option as the correct answer to a trial. These checkmarks were replaced with an icon that displayed the word "Yes."

Remove the detail disclosure button: The interface failed to make it clear to participants that each row contained two different navigation items and that touching the detail disclosure button navigated to a different section than simply touching the row. As a result, the iPhone version was changed to use a disclosure indicator button, with one link for the entire row. In the iPad version, a Start button was added to the rows to start the program.

Add label to the action button: In order to add media, users needed to tap the Action button before selecting the media source, but the Action button did not provide participants with any clue to its purpose, unless the participant actually tapped it so that the Action menu was displayed. Consequently, some of the subjects struggled with finding the button for adding media, although they noted that they would remember its function the next time. A label that displayed "Add Media" was added next to the Action button to describe its function.

On the iPad move the start button to the top of the screen: The Start button on the iPad version was originally located at the bottom of the screen. It was relocated to the top of the Programs page in order to provide quicker access to starting a program.

Move trial details below trial objects: The original Trials page included Edit and Action buttons in the toolbar, followed by the Details section and the trial objects at the bottom of the screen. Participants failed to notice that the buttons in the toolbar were used for editing trial objects, since the trial objects were located below the Details section instead of being located directly below the buttons in the toolbar. This finding was in line with the proximity concept in Gestalt laws of grouping, which describes how human “perception tends to group stimuli that are close together as part of the same object, and stimuli that are far apart as two separate objects” (Davey & Field, 2014). As a result, the trial objects were moved above the Details section.

Second Interactive Prototype (jQuery Mobile App)

Several design principles were considered in the design of the second prototype’s user interface. One of the findings from the first prototype’s user tests was that users did not associate controls with elements that were incorporated at a distance from those controls. Gestalt law of proximity states that objects that are closer together are perceived as more related than objects that are further apart (Perls, 1992). The second prototype’s user interface employs the Gestalt law of proximity to place controls and their related elements on the interface close to each other when possible so that users can easily see them as related. For instance, the Add New Program button displays a popup next to it where the program types are grouped together. Similarly, the Start, Assign, and Setup buttons are included next to each other in a separate container and are displayed on top of the existing programs.

In order to support the user’s mental model and reduce learning time, visual elements and interactive components were employed consistently across all sections of the second prototype’s interface. A mental model, according to Jakob Nielson (2010), is what the user believes about the system at hand and how he or she predicts it to function. Users build their mental models based on their prior knowledge of similar interfaces and their experience with the current interface. In the second prototype application, the left panels employ the same push mechanism to open across all screens, and the controls for opening, closing, and editing them are always in the same location in all the sections that include a left panel; this supports users’ expectations once they are familiarized with the interface.

Control buttons across the second prototype interface use text labels with icons. Using icons aids in scannability, leads to immediate recognition, and facilitates recall (Wiedenbeck, 1999). The combination of icons with text allows for disambiguating the meaning of the control choices available on the interface. In her study, Wiedenbeck (1999) found that icons with text labels were easier for participants to recognize correctly. Her study indicated a learning advantage for the label-only and icon-with-text interfaces as compared to the icon-only interface for correctness, time, and use of help. On this basis, the interface buttons in the second prototype application use simplistic icons with text; these appear consistently across the user interface (Figure 5.3).

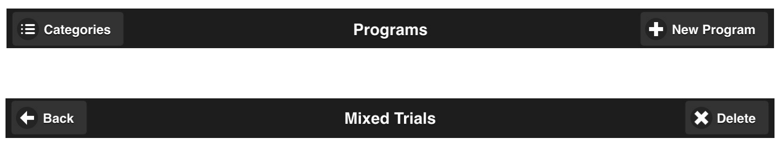

Figure 5.3. Interface buttons

The original four sections (Programs, Students, Objects, and Settings) were modified for the second prototype, and some sections were renamed. The Settings section was removed, and its functions were rolled into the programs themselves. It was replaced with a Notifications section (later renamed Dashboard), which displays progress updates about student activities and their assigned programs. As mentioned earlier, the Objects section was renamed Library, because it contains all the pictures, videos, animations, and multimedia stimuli that can be incorporated into the programs. The Students section still includes a list of enrolled students, and allows accessing their Individualized Education Program (IEP), assigned exercises, and training history. The Programs section displays the available exercises in the system, and allows modifying existing programs or adding new ones.

The next section discusses the results from the second prototype user tests and provides a description of the changes that were incorporated to improve the interaction design of the application.

User Study Findings

To evaluate the usability of the second prototype, two pilot tests and twelve user tests were conducted. The pilot tests preceded the user tests and aided in the preparation for the user tests. The findings from the pilot and user tests and a discussion of how these findings were incorporated to improve the interaction design of the application are provided in this section.

Two users with expertise in user experience and website usability participated in the pilot tests, and several decisions about the user interface were made based on these pilot tests. For example, the Notifications section was renamed to "Dashboard" and also made the default screen (first tab instead of last) because the pilot test users suggested that would be a better match to its purpose as the application's "homepage," where teachers are able to see an overview of their students' progress. Another change requested by the pilot users was the addition of a thumbnail in the Program list for each program and an indicator of the number of trials in each program. On the Trials screens (once users start a program), an indicator was added to show the remaining number of trials and display the user progress through the trials (e.g., 1/10). On the Program Setup screen and the New Program screens, the Add Media button was relocated from the top right side of the toolbar to the Target Skills section in the middle of the screen. Trial media used to be located on a different screen than the general settings. Moving between the Settings screen and the Objects screen was found confusing. To address that, the interface was redesigned to include Trial media under multiple tabs in the same screen as the general settings. In the Library, users were originally required to tap on the image caption for selecting it, but the pilot users expected to be able to tap on the image itself. The image-select behavior was changed to allow users to tap on the image or the caption area. In addition, the icon for modifying the media items was changed from a gear icon to a pen icon. Another improvement to the application, which was suggested by the pilot users but not added until after the user tests, was to allow variations of each media to be saved in the Library (Figure 5.3). Although this functionality was initially considered relatively unimportant (and thus not included after the pilot tests), the findings of the user study strongly reinforced the need to include multiple versions of each stimulus in order to provide better generalization of the target stimuli and also allow for customizing target stimuli based on children's special needs.

The following are additional changes that have been incorporated based on the results from the user tests. On the Program Setup screen and the New Program screens, “Randomize” was renamed to “Random Rotation,” which is an established term, in order to clarify its purpose. After discussing with DTT specialists, the terms “mass trials” and “mixed trial training” were used instead of “rote teaching” and “MET” (Multiple Exemplar Training), which had initially

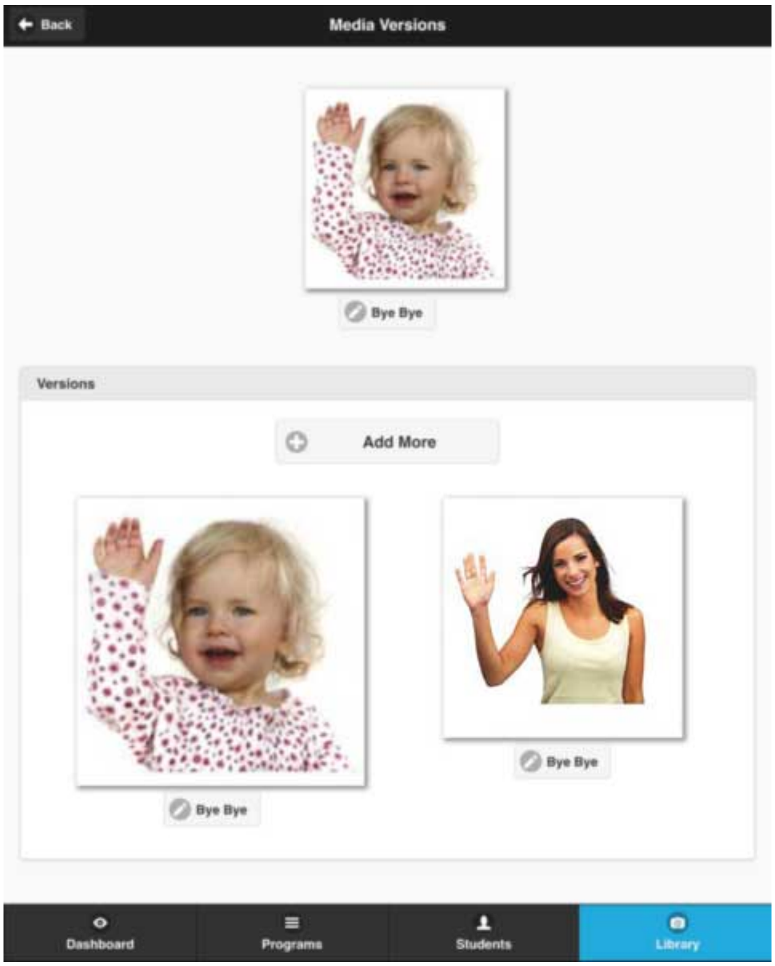

Figure 5.3. Media variations

Note. Pictures courtesy of babysignlanguage.com

been employed, based on an article by Venkatesh et al (2012). To provide further clarity, “Initial SD” was renamed to “Initial verbal instruction,” “Reinforcement” was renamed to “Reinforcement praise for correct answer,” and “Prompt” was renamed to “Prompt if wrong answer received.”

It was observed that once users completed configuration of a program, they would arrive at the bottom of the screen, where they expected to be able to save the program. As a result, the Save button, which was originally located in the top right corner of the toolbar, was exchanged with the Delete button, which used to be located at the bottom of the screen, so that users would see the Save button instead of the Delete button after they finished configuring the program. In order to make the Program Setup screen and New Program screens less busy, the verbal instruction, prompt, and reinforcement options for first try, second try, and last try were incorporated in expandable lists (Figure 5.4). After a program was completed, a summary of the results was included, with an option to allow the student to take the program again.

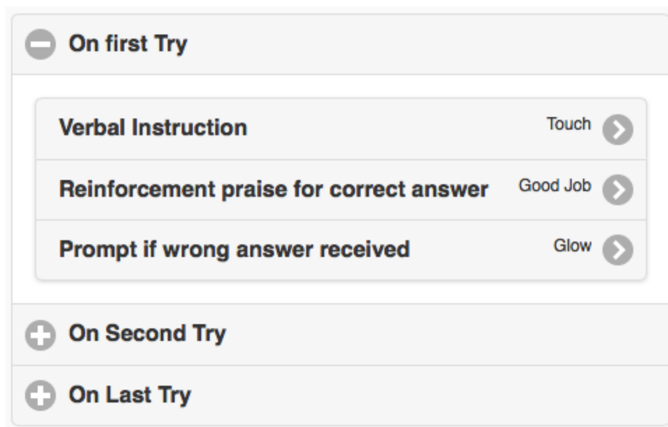

Figure 5.4. Expandable lists

On the Trials screens (once users start a program), the "point to" instruction was changed to "touch," in order to place stress on touching the interface. The "nice try" reinforcement was removed, since it was not descriptive of either a correct or an incorrect attempt. In addition, an option was included to limit the field size to fewer stimuli after incorrect answers. Based on the study participants' suggestions, a change was made so that an item was highlighted when it was touched in order to provide visual feedback to indicate that the user had selected the item. For moderated trainings, where the student must perform a skill in imitation of one shown on the device (e.g., video modeling training), the following options were included for the moderator (an instructor, therapist, or parent) to input for the trial: Prompt – Correct – Incorrect – No Response (Figure 5.5).

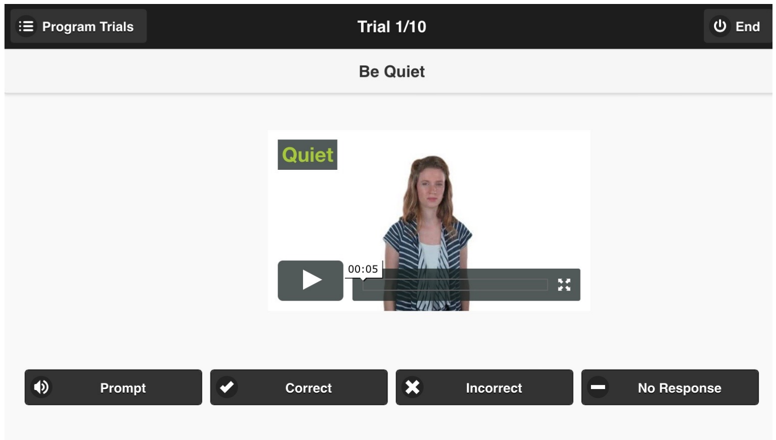

Figure 5.5. Moderated training options

Note. Pictures courtesy of babysignlanguage.com

On the Student Profile screen, the Assign button was added to the top right corner of the toolbar to allow instructors to assign a program to the student. In the Recent Trainings section of the screen, the latest completed programs were displayed and the interface was allowed to expand the list to view more. Based on the participants' feedback, the assigned-date line was expanded to also indicate who assigned the program to the student. A Statistics section with a time range was added that allowed educators to view the student's training progress (Figure 5.6).

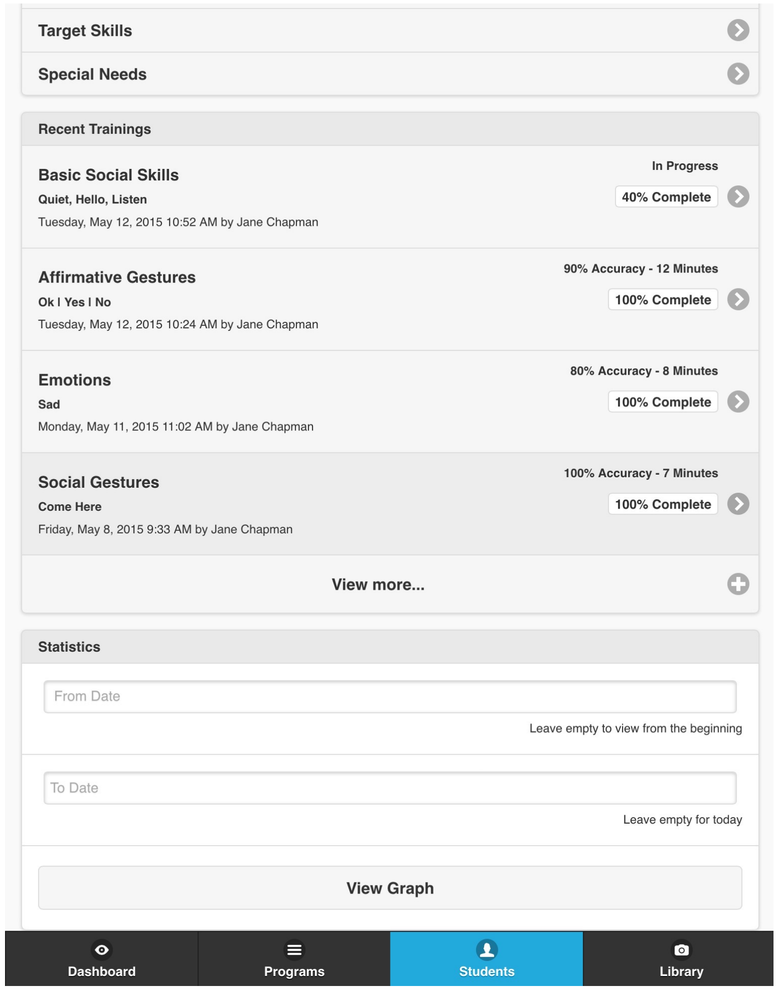

Figure 5.6. Student Profile

A number of findings were considered out of the scope of this project and were recorded for future implementation. Because most children enjoy visual elements, providing more fun elements—such as animations, exploding pictures, dancing characters, balloons, firecrackers, video clips, etc.—to help with their engagement was strongly suggested. Research on the effects of color in teaching individuals with autism shows that color can be effective in reducing their difficulties in reading (Dzulkifli & Mustafar, 2013). In their study, Ludlow & Wilkins (2009) show an improvement of reading speed up to 35% for autistic children reading using a colored overlay compared to no overlay. According to Dzulkifli and Mustafar (2013) color can increase chances that environmental stimuli will be encoded, stored, and retrieved successfully and results in improved memory abilities. In a case study of new possibilities for learning through animation, Holmgaard, Pedersen, and Abbott (2013) found that the participants in their case study achieved greater learning gains through their involvement in animation.

A suggestion by one of the specialists was to allow students to pick their own reinforcement based on their preferences. The design of the application was based on allowing educators to customize the training according to the children's needs; however, allowing high-functioning children the option of choose their own reinforcement from a pre-selected list could be useful. In addition to auditory reinforcements, some other examples of positive reinforcements that can be used include tangible items, edible foods, preferred activities, and free time. Timing is important in providing reinforcements. Reinforcers should be provided directly after the successful completion of the trial or program. It is also important to provide reinforcements that the child does not already have free access to. Moreover, it is helpful to choose a reinforcer that can be continual and enhanced. Individuals respond to reinforcements differently and allowing the children to choose their preferred reinforcement can lead to increased motivation and engagement.

In addition, it would be helpful to allow custom instructions, reinforcements, prompts, and themes to be set universally for each student, in addition to being able to set those preferences for each program. This would allow educators to customize each program based on the particular needs of the student more easily. Customizing the program to use larger text, for instance, was one of the suggestions in the user study and should be incorporated as a setting in the student profile section of the application. This suggestion came late in the study and could not be implemented prior to the end of the study.

Another suggestion by one of the specialists was to use verbal instructions in context. For instance, instead of saying, "Be quiet," say, "We are in the library; be quiet." Verbal instructions are configurable in the Library, and educators can record their own verbal instruction for a target skill. Research shows that providing meaning and context helps learning (Williams, Lombrozo, & Rehder, 2010). Context allows people to find a pattern, which facilitates learning. Therefore, educators should consider adding instruction that includes a context in order to provide meaning to the target skill and allow for further generalization of the training to natural environment situations.

Learning styles differ significantly among individuals and autistic children exhibit different strengths when it comes to learning. While some children are predominantly auditory learners and interpret the underlying meanings of speech through listening to tone of voice, pitch, speed and other nuances, others tend to be visual learners and learn more effectively by seeing the teacher's body language and facial expression. On the other hand, some children are tactile learners and learn best through touching, moving, and doing. As a result, educators should consider using both auditory media and videos in moderated sessions. Moderated sessions are trainings where the child's response is monitored and entered into the system by the educator. Allowing the educator to input their prompt type (e.g., physical, verbal) in the system can assist in data collection and would help with identifying and supporting each child's learning needs.

More complex activities such as trivia, multi-step programs to teach order, and social stories can be used to teach additional types of skills. Daily routines can be broken up into a list and implemented as trials in the program to check as the day goes on. An example program could be wake up, wash face, eat breakfast in the kitchen, clean up breakfast, brush teeth, make bed, etc. Combining various types of training helps children learn additional skills and reinforces different abilities such as sorting, matching, ordering, and sequencing.

In addition, graphing the student's training progress was not implemented in the current version of the application, since the focus of the app at this stage was on the design of the interface, not the execution of the data. However, the requirements for graphing the data were collected and are discussed in the next chapter. Graphs can can help educators understand and interpret the data more quickly, and can improve and simplify the reporting process. They will also help in identifying and reporting trends over time.

Finally, the functional version of the app should include an introductory walkthrough for first-time users in order to teach them the main components of the interface. Providing popup tips when users hold down an element should also be considered in order to help users learn the different functions of the application. The app can take the first time users through the flow of creating a program. Coach marks can be used to indicate the actions that can be performed on the application. These instructions should not repeat for returning users, but they should be accessible via a help mechanism. Providing an introductory tutorial to first time users and tips about each control can reduce learning time and increase user confidence.

Two suggestions were discarded among the findings. They included renaming “Media” to “Response Option” and clarifying the difference between “Trials” and “Tries” in each program. The cumulative results from the tests showed that these issues occurred only once and the terms were clear to the rest of the users in the study. Future user studies can be conducted to evaluate if more users share these problems.

Table 5.1 provides a summary of the users’ feedback and findings from the user testings and outlines, noting whether they were incorporated to improve the application, discarded, or recorded for future implementation.

Table 5.1

User study findings

Participant	Findings	Outcome
P1	Clarify the role of dashboard in an introduction walkthrough	Accepted
	Clarify “Randomize”	Accepted
P2	Provide templates for programs	Accepted
	Allow custom instructions, reinforcements, prompts, and themes for students	Postponed
	Include more visual fun elements	Postponed
P3	In the prototype match student names on Dashboard and Students sections	Accepted
	Allow programs to be assigned to students from Students section	Accepted
P4	Change “nice try” to a reinforcement that indicates correct answer	Accepted
	Suggest IEP programs based on student needs	Postponed
P5	Incorporate fun animations e.g., exploding pictures and dancing characters	Postponed
	Limit the field size to fewer stimuli on incorrect answers	Accepted

	Add more complex activities such as trivia	Postponed
	Randomize SD sound	Accepted
	Allow configuring stimuli size to use bigger or smaller media in trials	Accepted
P6	Limit the field size to one on the last try	Accepted
	Use engaging animations such as explosions for reinforcement	Postponed
	Illustrate progress using graphs	Accepted
	Store training history over years	Accepted
	Allow students to pick their reinforcement based on their preference	Postponed
P7	Allow using multiple different stimuli for each target in a program	Accepted
	Reduce the field size after each incorrect answer	Accepted
	Use larger pictures	Accepted
	Use larger text	Postponed
	Redesign the new program screen to be less busy	Accepted
	In student profile display the latest programs and allow expanding the rest	Accepted
	Indicate who has assigned a program to student	Accepted
P8	In the prototype change the "point to" SD to "touch"	Accepted
	Display how many times each program was taken in student's history	Accepted
	In the prototype, add "delete" button to new program screen	Accepted
	Display fun animations such as balloons on program completion	Postponed
	Include multistep programs to teach order	Postponed
P9	Provide a walkthrough for first time users	Postponed
	Clarify the difference between "trials" and "tries" in each program	Rejected
P10	Include social stories for natural environment exercises	Postponed
	Provide premade templates as well as allow building custom exercises	Accepted
	Provide visual feedback when an object is touched	Accepted

	Use instructions in a scenario to provide context	Postponed
	Remove “training material” from students’ IEP section	Accepted
	Allow assigning programs from students’ profile and dashboard	Accepted
P11	Rename the option on third try from saying “Nothing” to “Display answer”	Accepted
	Rename “Media” to “Response option”	Rejected
	Rename “Initial SD” to “Initial verbal instruction”	Accepted
	Rename “Reinforcement” to “Reinforcement praise for correct answer”	Accepted
	Rename “Prompt” to “Prompt if wrong answer received”	Accepted
	Include a large “Save” button at the end of new program screen	Accepted
	Provide popup tips when users hold down an element	Postponed
P12	Replace “Delete” button with “Save” on the add new program settings	Accepted
	Consider that media can be just auditory	Postponed
	Allow turning sound off for kids with aversion to sound	Accepted
	When a program is complete display a summary and allow practicing it again	Accepted
	For moderated trainings allow moderators to input their prompt type (e.g., physical, verbal) for data collection	Postponed
	For moderated trainings use the following options: Correct – Prompt – Incorrect – No Response	Accepted
	Rename “Rote teaching” to “mass trials” and “MET” to “mixed trial training”	Accepted

Chapter 6: Conclusion

The goal of this project was to provide a mobile platform based on Discrete Trial Training for teaching high-functioning autistic children. A web-based mobile app was developed and a number of requirement specifications were identified that describe the requirements for building future mobile apps.

Based on the literature review and findings from the user tests, a mobile app that aims at providing training to students with autism needs to be highly customizable to support the unique needs of each individual on the spectrum, including each student's sensory input needs and educational requirements. It needs to be mobile in order to allow learning to occur independent of classroom settings and to help with generalization of the training. Moreover, it needs to record students' progress over time and display the data in graphs, where time is represented on the x-axis and skill acquisition on the y-axis of the graph. And finally, along with all this flexibility, mobility, and reporting capability, the resulting application needs to be easy to use.

To support these requirements, Wave's interface includes four main sections: Dashboard, Programs, Students, and Library. The Dashboard provides a quick overview of ongoing assignments. The Programs section lists the available programs, which can be organized in categories as well as allowing for the creation and customization of new exercises. The Students section lists the currently enrolled students, along with their special education needs, and provides an interface to monitor their progress over time. The Library includes the discriminative stimuli, such as images, videos, animations, etc., that are used to teach the target skills; it allows additional items to be downloaded from the Internet or captured from the device.

The application provides the option to easily create system-generated programs or customize a program to fit the specific needs of individual students. It supports two types of system-generated programs: mass trials and mixed trials. Mixed trials allow for selecting multiple stimuli, while mass trials teach one skill at a time. The build-your-own option allows educators to customize each trial within the program, adjusting them to a student's particular needs.

The Wave mobile app can help to develop basic skills, including attention, perception, reasoning, memory, reading and writing, motor skills through matching skills, imitation exercises, and natural environment trainings. It allows programs to be customized and enables adjustments to be made to fit the specific educational and physical needs of an ASD child. Its portability supports learning at any time and in any location and allows the learning process to be transferred to natural environment settings, including family and public settings. Furthermore, it helps teachers to save time by allowing them to reuse programs and decreases their workload by offering them easy access to monitoring children's data.

According to the specialists who participated in the user testings, the Wave application is practical and usable for teaching children with autism. Having every single trial presented in exactly the same way every time—a need of ASD children—is likely to be impossible for human trainers; however, the Wave app enables that requirement. For parents who are interested in training their children at home or in other natural environments, the app offers programs that are exactly the same as those provided by the teacher, which allows parents to deliver the training in the same manner.

The Wave app makes it easy for the teacher to monitor a student's data and eliminates the variability of different people recording data in different ways. Storage of the training data helps even new teachers to understand a child's learning history and determine what skills have been mastered in the past, which assists teachers in creating new skill acquisition programs or maintenance programs that focus on the skills that have been previously mastered.

The mobile application still requires a number of components in order to be made functional for educational use. The current Wave app is a working prototype without a database to store information. As a result, several sections of the application had to be statically created to present the interaction design of the interface for the user tests. The app will need a database to be implemented in order to store the application data, including the list of programs, students, and media items, and to allow students' progress data to be displayed in graphs. It will also require an algorithm to execute the programs and present the trials to the users.

In addition, a fully functional version of the application will need to restrict students' access to other sections of the app, as well as any other apps that might be available on the device. Autistic children can be quite well versed in using iPads and could easily navigate away from a training application to their favorite apps. The Wave application will include a Student Mode that will restrict user access to a list of assigned programs that are available for the student. This feature will help by displaying only relevant information to the student and prevents students from altering other sections of the application.

A number of other enhancements should also be considered for future implementations. Most children show interest in visual media, which can be used to increase engagement with the application. Fun animations, exploding pictures, dancing characters, balloons, firecrackers, video clips, etc. could be used as reinforcements for correct answers. During the user tests, ASD educators noted that many autistic children enjoy watching their favorite video clips over and over again. Allowing kids to choose their preferred reinforcement from a list of preselected items can aid in raising their enthusiasm and increasing their engagement. In addition, it would be helpful to allow custom instructions, reinforcements, prompts, and themes to be set universally for each student, in addition to being able to set those preferences for each program.

In terms of adding enhancements that will assist teachers and parents in using Wave, the functional version of the app should include an introductory walkthrough for first-time users in order to teach them the main components of the interface. Providing popup tips when users hold down an element should also be considered in order to help users learn the different functions of the application. As instructors become more expert in building programs, they can consider adding more complex activities such as trivia, design multi-step programs to teach order, and create social stories that are not provided by the default in order to teach additional types of skills. Instructors should also note that it is beneficial to provide customized verbal instruction in a context (i.e., "We are in the library; be quiet") in order to allow for further generalization of the training to natural environment situations. Although the target stimuli demonstrated in this version of the app were visual media, instructors could also consider auditory stimuli for the purpose of building programs.

It should be noted that using computer-assisted inteventions to teach social skills can pose generalization issues. Generalization refers to the transfer of a skill that is learned in one setting—such as a device—to the second setting—such as the natural environment—without explicit teaching in the second transfer setting. Once a skill is learned on a device, it is important that the person is able to naturally start using those skills in the real world. In many cases, social skills generalize naturally, especially in typical child development. However, for individuals with autism generalization may not happen as predictably (Autism Ontario, 2011). Additional research on the generalization of computer-assisted interventions is required to better evaluate the efficacy of such technology in teaching nonverbal social communication skills to individuals with autism.

Finally, future randomized controlled studies of the application in use by ASD children will be required to evaluate the efficacy of the Wave application in teaching nonverbal social communication skills to high-functioning autistic children using Discrete Trial Training. Controlled trials should include enough participants to yield statistically significant results, and they should employ randomized designs to eliminate the influence of confounding variables.

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Appendix A: First Prototypes Interview Script

Thank you so much for coming in today. My name is Amir Chamsaz. I wanted to give you a little information about what you will be doing and give you time to ask any questions you might have before we get started.

Today I am going to be asking you to perform a few tasks on a prototype for a mobile app for teaching nonverbal social skills to high-functioning autistic children. Our objective is to better understand the app's usability. These tasks are in no way testing you. Rather, they are all about how easy we have made it for people to use this app. If something doesn't work or a task seems impossible, it is absolutely the fault of the app itself. The whole process should take no more than one hour.

Before each task begins, I will place a paper slip with the task description in front of you. When you see it, please read each task aloud, and then you can start to work. As you are working through the tasks, I'd like to ask you to "think aloud." What we are looking for is basically a running commentary about your thoughts as you move through the app. We mostly want to know what's going through your head as you work.

If you have any questions, comments, or areas of confusion while you are working, please tell me. I may not always be able to help you, but it is very important for us to note where questions come up.

As you go through the tasks, I may stop you to ask for clarification about your process or to find out what you are thinking at that moment. It is important that you tell me when you feel that each task is complete. I will not be stopping you when you finish each task, so please make sure to tell me when you feel that you have finished.

Your comments today are going to be really helpful for improving our project, so thank you again for helping me.

Do you have any questions for me before we begin?

Appendix B: First Prototypes Task Scenarios

We are going to test two versions of an application, first on the iPad and then on the iPhone. Both interfaces are very similar, although they include differences. I would like you to try both and let me know what you think about them. It is important to keep in mind that I am testing the interface and not you, and I am interested to see what difficulties users may have in accomplishing their goals.

The application is an educational tool for teachers, therapists, and parents to teach their children various concepts using the Discrete Trial Training method. Every program consists of a number of trials where object items are presented to the children and they are asked to touch the correct object according a verbal instruction for the trial.

I have three activities for you to complete. Please think aloud and let me know what goes through your mind while interacting with the application. Your first task is a simple action that familiarizes you with the interface.

Activity 1: You have already created a program called "Money Concepts." Please go to that program and run it for the child to play.

Activity 2: You are interested in changing an item on the first trial of the Money Concepts program. There is a Canadian nickel among the trial objects that you would like to change with an American nickel from your objects library. How would you change it?

Activity 3: Kids can answer a question up to three times in each trial. After each error, a prompt will be provided as a clue to the correct answer (i.e., shaking the correct answer and zooming in to it). These prompts and the instruction for each of the three tries can be customized. Where would you go to adjust those customizations?

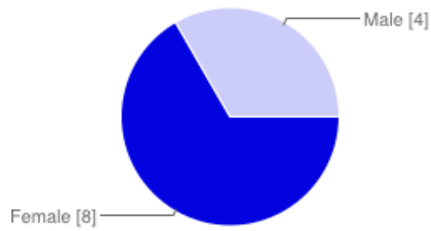
Follow-up question: What do you think about the interface? Do you have any general comments?

Next Platform: We move now to the other device (iPhone or iPad) to test the same tasks. I am going to repeat the activities for you.

Ending follow-up question: Which interface did you like better and why? What would make this app better? Do you have any further comments?

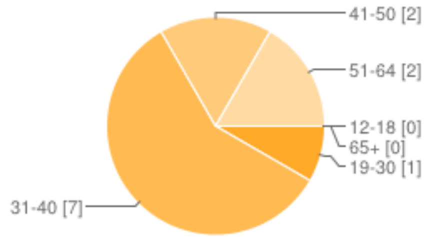
Appendix C: Second Prototype Participants

Please select your gender group.



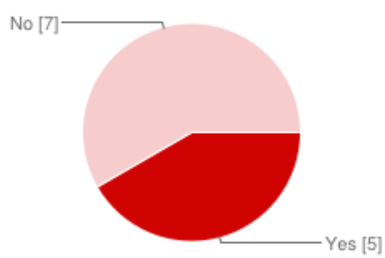
Female	8	66.7%
Male	4	33.3%

Please select your age group.



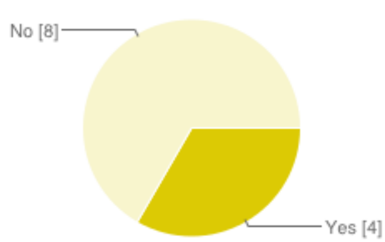
12-18	0	0%
19-30	1	8.3%
31-40	7	58.3%
41-50	2	16.7%
51-64	2	16.7%
65+	0	0%

Do you work with students with special needs?



Yes	5	41.7%
No	7	58.3%

Do you provide training to students with Autism Spectrum Disorder?



Yes	4	33.3%
No	8	66.7%

Appendix D: Second Prototype Consent Form

The purpose of this interview is to better understand the need for designing exercises that support autistic children's training requirements for learning non-verbal interactions, including gestures.

The interview will approximately take one hour, where you will be presented with a few tasks to carry out using a mobile app. Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. You will not be penalized in any way should you decide not to participate or to withdraw from this study.

The interview session will be recorded in order to supplement note taking. The video will not be viewed by anyone other than my research committee and me. The results of the research may be shared in a publication, but no individually identifiable information will be shared.

If you have any questions about the research, you may contact the following individual:

Kathryn Summers, Ph.D.
(Faculty Advisor)
ksummers@ubalt.edu
(410) 837 6202

For questions about your rights as a research participant, please contact:

Dr. Eric Easton
(IRB Chair)
eeaston@ubalt.edu
410 837 4871

Thank you for your participation.

I understand the study described above and permit the interviewer to observe my research behavior and videotape the session for research purposes. I am 18 years of age or older and I agree to participate.

____________________________________ ____________________

Signature of Participant Date

Appendix E: Second Prototype Interview Script

First, I would like to provide you with a background about the project. This project uses Discrete Trial Training to teach nonverbal social skills. The purpose of this project is to deliver customizable Discrete Trial Training through a mobile app, where programs can be built once and shared and reused over time.

In the DTT method, skills are taught in small, repeated steps. To achieve that, each program teaches one or multiple skills across a number of trials. A trial starts with an instruction called *discriminative stimuli* (such as “touch goodbye”). If the child identifies the correct answer, a *reinforcement* (such as “good job!”) will be provided and the exercise moves to the next trial. After each incorrect answer, a *prompt* (such as highlighting the correct answer) will be provided as a clue to the correct answer.

Exercises can be built in one of the three types: mass trials, mixed trials, and build-your-own (custom). The mass trials type focuses on only one target at a time throughout the program. Mixed trials allows the user to add programs with multiple targets. The build-your-own option allows users to customize each trial within the program, adjusting them to a student’s particular needs.

This application is a prototype, so not all elements on the interface are functional, but I encourage you to try any element that you want. The app will be available in two versions: Wave Teacher, which allows teachers to build programs, and Wave Student, which is a stripped down version and only includes the programs for kids to play. I am using a text-to-speech voice that might not sound natural, but please just consider that as a prototype example that will change to a more engaging human voice.

I have four activities for you to complete. Please think aloud and let me know what goes through your mind while interacting with the application.

Appendix F: Second Prototype Task Scenarios

Activity 1: You have already created an exercise called “Getting Started” to teach three nonverbal gestures: *Bye Bye*, *Come Here*, and *Be Quiet*. Please go ahead and play that exercise.

Activity 2: You are interested in building an exercise to teach *Be Quiet*, *Hello*, and *Listen*, where *Be Quiet* is presented on the first trial, *Be Quiet* and *Hello* are presented on the second trial, and all three stimuli are presented on the third trial.

Activity 3: Naomi Beck is one of the children you are working with. You have assigned a few exercises for her to complete. How would you check her progress and her training history?

Activity 4: You would like to use your own voice for the instruction that is played for the *Be Quiet* stimulus. How would you do that?

Follow-up: What do you think about the interface? Do you have any suggestions for improving the app?