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Using Virtual Reality Enhanced Behavioral Skills Training to Teach Street-Crossing Skills to Children and Adolescents with Autism Spectrum Disorders

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USING VIRTUAL REALITY ENHANCED BEHAVIORAL SKILLS TRAINING TO TEACH STREET-CROSSING SKILLS TO CHILDREN AND ADOLESCENTS WITH AUTISM SPECTRUM DISORDERS

by

Tina R. Goldsmith

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Tina R. Goldsmith
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INTRODUCTION

According to reports issued by the Centers for Disease Control (CDC) in 2003, the leading cause of death for children ages 1 to 14 is unintentional injury. Motor vehicle accidents make up the largest percentage of deaths; followed by drowning, fire related accidents, and suicide/suffocation. The number of children (0-15) who suffered from nonfatal, unintentional pedestrian injuries for the six-year period from 2001 to 2006 reached 254,683. With a population estimate of 389,450,422, the resulting rate is around 65 per 100,000. Although the CDC collects a wealth of statistical information, including age, sex, and race/ethnicity, information regarding disability/diagnosis of the injured person is not collected. Nevertheless, it is clear that children are at risk for unintentional injury, but children with disabilities, including those with Autism Spectrum Disorders (ASDs), are a particularly vulnerable population (Shavelle, Strauss, & Pickett, 2001; Isager, Mouridsen, & Rich, 1999; Brenner, 2003). The pervasive delays evident for children with ASDs requires caregivers, clinicians, and researchers to be mindful of the need for efficacious treatments that will not only improve the quality of life for these individuals, but will also serve to keep them safe as they become increasingly independent.

The DSM-IV-TR diagnostic category of Pervasive Developmental Disorders (PDDs) includes Autistic Disorder, Asperger's Disorder, and Pervasive Developmental Disorder Not Otherwise Specified (American Psychiatric Association, 2000). With impairment in social functioning at the core of these three disorders, they cluster together and are commonly referred to as Autism Spectrum Disorders (ASDs). The impaired
social functioning that is characteristic of children diagnosed with an ASD negatively affects the performance of social, self-help, and safety skills. Insensitivity to subtle environmental cues and poor problem solving in the face of stressful tasks contributes to their impaired skill use (Mesibov, Adams, & Klinger, 1997; Shavelle, Strauss, & Picket, 2001) and creates unique challenges when developing teaching strategies for this population. Although there are no reported statistics for the number of accidents and injuries sustained by individuals with ASDs each year, ongoing research conducted in part by the Autism Tissue Project, a joint effort of the Autism Society of America (ASA) Foundation, the National Alliance for Autism Research (NAAR) and the Medical Investigation of Neurodevelopmental Disorders (M.I.N.D.) Institute at the University of California, Davis, provides us with information about the relationship between accidental injury and death in individuals who are diagnosed with an ASD. Researchers have evaluated the causes and frequencies of death in persons with autism as compared with the general population. Shavelle, Strauss, and Picket (2001) reported data for 13,111 ambulatory Californians with autism who were followed between 1983 and 1997. Elevated death rates were observed for several causes, including seizures and potentially preventable accidents such as suffocation and drowning. Overall, excess mortality was especially marked for persons with severe mental retardation, but life expectancy was reduced even for fully ambulatory persons with mild mental retardation, which is a notable finding given the comorbidity that exists between autism and mental retardation. This research further supports the notion that individuals on the autism spectrum are at an increased risk for accidental death and highlights the need for the development of efficacious safety skills interventions for this population.
Traditional Options to Reduce Accidental Injury and Death

Families that include a child with an ASD commonly deal with unsafe behavior by modifying the family’s environment to prevent the opportunity for safety-related errors and their potentially harmful consequences (Waltz, 2002). That is, caregivers attempt to provide constant supervision and limit access to potentially dangerous items and situations such as street crossings, open bodies of water, and kitchen appliances. For younger children, constant supervision and access constraints may prove to be a successful but effortful approach that results in some degree of limitation to their child’s freedom and independence which might be considered a small price to pay for safety. However, for older children and adolescents with ASDs, constant supervision and access constraints may prove nearly impossible and may negatively impact life opportunities. Active teaching interventions that build independent safety skills may increase safety and allow greater independence.

Although there is an apparent need for active safety skills training with all children, the most effective means to teach safety skills with clear improvements that generalize across settings is not as readily apparent. For example, the American Academy of Pediatrics (Brenner, 2003) suggests that prevention of drowning in infants, children, and adolescents is best accomplished with “layers of protection” (p. 442). They recommend environmental modification strategies such as installation of four-sided fencing, the use of pool covers and alarms, adult supervision, the use of personal flotation devices, and swimming instruction. However, they admit that while swimming
lessons improve swimming ability, there are no data to show that swimming lessons actually decrease the risk of drowning.

Optimal intervention strategies remain unclear with other safety skills as well. In the area of personal safety, parents and educators have targeted areas such as pedestrian, fire, abduction, fire-arm, and drug safety with varied success (e.g., Hardy, Armstrong, Martin, & Strawn, 1996). These programs typically include one-part teaching strategies such as reading books, watching videos, providing live didactic instruction, performing plays, and presenting puppet shows. However, multi-component interventions consisting of a combination of these one-part strategies are also common and have resulted in improved success over one-part strategies such as didactic instruction (e.g., Himle, Miltenberger, Flessner, & Gatheridge, 2004). Many educators and parents may assume that effective training requires little more than didactic instruction with at least some entertaining value using clearly delineated steps and rules; however, the consequences associated with even a single failure to use the targeted skill in a dangerous situation requires evidence of behavioral change as well as change in knowledge. Unfortunately, little empirical data exists to support the use of simple didactic strategies for effecting behavioral change.

Hardy, Armstrong, Martin, and Strawn (1996) evaluated a straightforward didactic instruction program to reduce gunplay. These researchers observed the behavior of 24 pairs of 4-6-year-old children before and after they received an education-based intervention on the dangers of guns and the appropriate actions to take when a gun was found. In collaboration with a police officer, they presented information regarding the dangers of firearms and instructed the children (a) not to touch guns and (b) to tell an
adult immediately if they ever found one. Unfortunately, behavior observed following the education-based intervention showed that this instructional approach failed to decrease the children's gunplay behavior.

More recently, Hardy (2002) evaluated the effectiveness of a “skills building” approach for teaching gun-safety skills to children. The goal of the program was to teach children to discriminate between real and toy guns, to resolve problems without resorting to the use of aggressive behavior, and to make safe decisions (including not touching the gun and telling an adult if a firearm is found). Although the detail provided in the article results in some ambiguity about the procedures used to teach these skills, results indicate that the children were no less likely to touch or handle a firearm after participating in the program.

In another recent study, Himle et al. (2004) evaluated the National Rifle Association’s Eddie Eagle gun safety program, a commercially available program for children ages 4 to 6 years. Himle et al. found that the education-based approach of the Eddie Eagle program was successful for teaching children to verbally reproduce the desired skill steps when asked what they would do if they found a gun: (1) stop, (2) don’t touch, (3) leave the area, and (4) tell an adult. However, compared to no-treatment controls, the participants were not significantly better at performing the skills during role-play situations or when they were assessed in more realistic situations.

Limited treatment gains following traditional safety skills interventions have been demonstrated for skill sets other than gunplay behavior. Researchers have found a lack of correspondence between how children report they will behave in abduction situations and how they actually behave during in situ assessment (e.g., Carroll-Rowan & Miltenberger,
A lack of correspondence also exists between how children report they will act and how they are observed to act in role-play situations. For example, Padgett and Waller (1975) found that a North Carolina curriculum designed to teach pedestrian safety was effective in increasing traffic safety knowledge. However, behavioral observations conducted at post-test showed virtually no improvement in actual pedestrian skills.

As first put forth by Tutty (1990) and later reiterated by Bromberg and Johnson (1997), two critical issues must be addressed when conducting safety skills training: (1) children must acquire a certain body of information or knowledge after participating in a skills training program, and (2) acquisition of information is a necessary but insufficient condition to ensure program efficacy. Children must be able to use the acquired information to engage in appropriate behaviors when confronted with a potentially dangerous situation in the real world. All too often this second issue is overlooked when determining the efficacy of a safety skills training intervention. With a propensity for evaluating behavior in its natural context, behavioral clinicians and researchers have made headway in developing safety skills training programs that focus not only on acquisition of knowledge, but acquisition and use of safe behavior in their natural context.

Behavioral Skills Training (BST): The Early Literature

Basic behavioral interventions have generally proven effective in teaching a variety of skills with some limitations in generalization of effects. As early as 1974, Braukmann, Maloney, Fixsen, Phillips, and Wolf showed that a combination of instructions, rationale, demonstration, practice, and feedback during training, along with money for correct performance during post training, was effective in improving
adolescents' interview behaviors following treatment. Two years later, Minkin, Braukmann, Minkin, Timbers, Timbers, and Fixsen (1976) showed the same package to be effective in training conversational skills in university and junior high students, and the following year, Bornstein, Bellack, and Hersen (1977) used modeling, role play, and feedback to teach assertive behaviors to 8 to 12 year old children, and in 1978 the self-help skill of selecting clothing to produce a color coordinated outfit was taught by Nutter and Reid using these same primary teaching components.

In addition to the adaptive behaviors described above, these same basic components have been employed to teach safety skills for over 30 years. Page, Iwata, and Neef (1976) combined instructions, rehearsal with a table-top model, and feedback to teach pedestrian skills to teenagers and young adults with mental retardation. Yeaton and Bailey (1978) taught pedestrian safety skills to typically developing children using an instructional package which included describing the correct behavior, demonstrating the behavior, testing the learner's ability to report the information included in the previous two phases, and allowing practice in a safe environment with praise and corrective feedback. Average skill levels improved from 44% during baseline to 97% after training at one site and from 21% to 86% at a second site with maintenance at one-year follow-up. In a 1983 follow-up study, Yeaton and Bailey modified their pedestrian safety training program to teach street-crossing to kindergarteners and first graders. Adult crossing guards successfully provided instruction during a single videotape and role-play training session to several groups of children. Following training, a positive change in the children's level of appropriate street crossing was observed on the location of the original training as well as on a street where training did not take place. The researchers also
conducted a utilization analysis of the guard training program and results indicate that consistently high levels of street-crossing behavior cannot be produced by implementing only the "show and tell" portions of the training package. Similarly, results suggest that one is unlikely to produce consistently high quality guard training behavior by only giving written instructions describing how pedestrian training should be administered.

The components of instructions, modeling, rehearsal, and feedback have been successfully combined to teach other personal safety skills to young children. Poche, Brouwer, and Swearingen (1981) taught self-protection skills in response to abduction lures to children aged 3-5 in a school setting. One female and two males acquired the appropriate verbal and motor responses to all three types of abduction lures used by the researchers. Self-protection skills during behavioral observation increased from a pre-training safety rating near zero to a post training rating of six (the highest possible score) and generalized to novel suspects and locations. For one of the two students available for follow-up, this improvement was fully maintained at least three months following training. Jones, Kazdin, and Haney (1981) taught emergency fire escape procedures to five children in simulated bedrooms at their school, resulting in significant improvements in both overt behavior and the self-report of fire safety skills. The gains were maintained at follow-up two weeks after training ceased.

*Formalization and Evaluation of BST*

Although the components of the previously reviewed literature had various names, each component was nearly identical. A 15-year evolution culminated in the formalization of BST (Miltenberger, 2003) as a packaged intervention and sparked a series of studies from the 1980's to the present designed to determine if BST would
consistently prove superior to traditional didactic instruction for safety skills training. The formalized BST package is a four part teaching strategy that involves (1) clear explicit instructions for appropriate behavior, (2) modeling or demonstration of appropriate behavior, (3) rehearsal or practice of the appropriate behavior, and (4) feedback on the performance that occurred during rehearsal (Miltenberger, 2003). Since the 1980s, BST has been successfully applied to teach abduction-prevention skills (e.g., Carroll-Rowen & Miltenberger, 1994; Marchand-Martella, Huber, Martella, & Wood, 1996), pedestrian safety (e.g., Wurtele, 1990), gun safety (e.g., Himle, Miltenberger, Flessner, & Gatheridge, 2004; Keslo, Miltenberger, Waters, Egemo-Helm, & Bagne, 2007), and sexual abuse prevention (Egemo-Helm, Miltenberger, Knudson, Finstrom, Jostad, & Johnson, 2007) to typically developing children, typically developing adults, and adults with developmental disabilities; and one recent study used BST to teach social skills to an individual with Asperger's Disorder (Stewart, Carr, & LeBlanc, 2007). Results from these studies support the efficacy of BST, but do not directly address the question of whether BST should be the treatment of choice given the availability of other skill acquisition methodologies.

In 1988, Poche, Yoder, and Miltenberger compared the effectiveness of a videotape training program based on components of BST with other instructional methods for teaching kindergarten and first grade children abduction self-protection techniques. Four experimental conditions were presented: (1) an interactive videotape with BST components, (2) the interactive, multi-component videotape with no rehearsal, (3) a standard safety program routinely made available in the schools and consisting of didactic instruction, question-and-answer time, feedback, and the viewing of a brief film
warning of the dangers of going with strangers, and (4) no training. At post-treatment, in situ testing trials were used to determine if the children would behave in correspondence with the previously taught program. Results revealed that the BST-based videotape program with behavior rehearsal was highly effective in teaching children safe responses. In contrast, the standard safety program was effective with fewer than half of the children and three fourths of the children who received no training immediately agreed to go with researchers posing as abductors. This study suggests that rehearsal is critical for effectively teaching safety skills and that technology such as video, can be incorporated into a traditional BST model of instruction.

Wurtele, Saslawsky, Miller, Marrs, and Britcher (1986) compared the effectiveness of various educational approaches for teaching sexual abuse prevention skills. Seventy-one children from two grade groups (group 1: kindergarten and first graders; group 2: fifth and sixth graders) participated in either (1) a filmed, commercially available program condition, (2) a BST program condition (3) a film plus BST condition or (4) a no-treatment control condition. Both versions of the BST program were more effective than the film alone or the control condition in increasing sexual abuse prevention knowledge. In addition, post-treatment group comparisons suggested the superiority of the BST program for enhancing personal safety skills, and follow-up data suggest that the knowledge and skill gains were maintained for three months. However, it should be noted that skill gains were assessed via paper-and-pencil method rather than in situ post treatment testing trials. Despite this limitation, this study provides additional evidence that BST (with or without a video component) is more effective than traditional teaching methods.
Miltenberger and Thiesse-Duffy (1988) evaluated the efficacy of a commercially available program, *The Red Flag, Green Flag Prevention Book*, used by parents to teach their four to seven year old children personal safety skills. Participants' parents were either given a copy of the book and instructed to use it with their child or were given the same book with written instructions on how to use the book to teach personal safety skills in the most effective way. Results of this study demonstrated that a commercially available, parent-implemented prevention program did not generally produce the desired change in personal safety knowledge or skills. Children who did not achieve criterion performance after training with the prevention book went on to receive experimenter-implemented BST with the result that all children met mastery criteria for skills training in terms of their improvement in both knowledge and skills. Despite this promising result, maintenance of gains at two months follow-up was seen only in the older group (i.e., 6 to 7 year olds). Most importantly, the finding that the published program was not effective when used by itself by untrained parents is significant. Programs such as these were, and still are, widely used with presumed beneficial effects. Empirical results rather than presumed benefits should guide treatment decisions, and the empirical data from this study suggest that active rehearsal and reinforcement are necessary to promote skill acquisition.

*Enhancing the Effectiveness of BST with In Situ Training*

It is important to note that in traditional BST, modeling, rehearsal, and feedback typically occur in a contrived role-play situation rather than in the natural environment. Although BST is a promising intervention, there are limitations to the traditional use of the treatment package in a contrived context. These limitations include failed skill
generalization and limited maintenance. Generalization failures occur when the training context does not share an adequate similarity with the environment where skills will eventually be assessed and used, and limited maintenance frequently occurs when the newly developed skill repertoire is not robust enough to withstand periods without practice and reinforcement for correct skill implementation.

Four studies suggest that adding in-situ training (i.e., experience in the natural setting with immediate consequences) increases the efficiency of BST for individuals who initially failed to perform the skills correctly during in-situ post-test assessments. In the first, Haseltine and Miltenberger (1990) evaluated a BST program to teach self-protection skills to adults with mental retardation. The standard components of BST were used and the researchers were mindful to include a wide variety of situations and various inducements to promote generalization to the natural environment. In situ assessments were used to evaluate the participant's behavior in the natural setting when she was unaware of being assessed. During in situ assessments, if the subject failed to demonstrate the appropriate safety response in the presence of a confederate, the trainer appeared and implemented training. In other words, the correct response was rehearsed until the participant performed the skill without being prompted. This process of naturalistic assessment followed by training continued until the participant was able to show independent use of the skill during two consecutive assessments. For seven of the eight adults, improvements in self-protection skills were maintained at 1 and 6-month follow-up, demonstrating the efficacy of BST. These results demonstrate that additional in situ training following in situ assessments may be essential to increase the efficacy of BST for some participants with mental retardation.
Miltenberger, Roberts, Ellingson, Galensky, Rapp, Long, and et al. (1999) evaluated the procedures for enhancing generalization following sexual abuse prevention skills training for five women with mental retardation. The participants received 10 BST sessions followed by in situ training when generalization was not observed in post-training evaluation. One participant demonstrated the safety skills following BST but the remaining participants achieved the skills after one to two in situ training sessions. At 1-month follow-up, all participants performed to criterion levels. The results showed that participants with mild to moderate mental retardation acquired the safety skills and demonstrated them in role-play assessments following BST, but that the skills did not completely generalize to naturalistic settings until in situ training occurred.

Similarly, Himle et al. (2004) used BST supplemented with in situ training for teaching gun safety skills to eight 4 to 5 year old, typically developing children. For the majority of participants (five of the eight), BST did not result in the desired skill use and generalization, but supplemental in situ training resulted in participants achieving the pre-established criterion for skill use with maintenance in all subsequent assessments and generalization to a new setting.

Miltenberger et al. (2004) evaluated BST in a multiple baseline across subjects design to teach firearm safety skills to six 6 to 7 year old typically developing children. Much like the previously mentioned study (Himle et al., 2004), half of the children acquired the safety skills following BST and half acquired the skills following BST plus in situ training. For one participant, it was necessary to add an incentive phase before skill gain was evident.
Three recent studies have incorporated in situ training into the core of BST rather than using it as an add-on component following failed success with traditional BST. Johnson et al. (2005) used BST with in situ training to teach abduction-prevention skills to pre-school children. All children demonstrated the desired skills during post-treatment in situ testing trials, thus demonstrating that BST with in situ training improved both acquisition and maintenance of abduction-prevention skills in preschoolers as compared to results from previous BST studies (i.e., 50% of children acquired skills and few maintained them at long-term follow-up).

Miltenberger et al. (2005) evaluated BST with in situ training for teaching gun safety to ten, typically developing, preschool children. Two sessions of BST with supplemental in situ training were provided, and children met criteria for skill acquisition. However, three participants failed to execute the skills during their first home assessment after training, suggesting that the skills did not generalize to the home environment. Despite initial generalization failures, successful use of the newly acquired skills was observed in the home following one to two additional in situ training opportunities. Researchers also demonstrated that, following training, children used the targeted safety skills when they found a gun in the presence of a peer. Although there was no specific within-study comparison of BST with and without in situ training, the researchers suggest that these results are superior to the effects of BST alone as evaluated by Himle, Miltenberger, Flessner, and Gatheridge (2004) and Miltenberger et al. (2004).

Most recently, Egemo-Helm, et al. (2007) sought to evaluate BST combined with in situ training early in training for teaching sexual abuse prevention skills to women with mental retardation (MR). Since previous research had examined the effects of BST with
in situ training implemented after a few training sessions and shown it to be more effective and efficient for teaching prevention skills to children (e.g., Johnson et al., 2005; Miltenberger et al., 2005), the researchers felt that if in situ training was implemented earlier, training may be more efficient and more effective, thus decreasing the amount of exposure the participant has to simulated sexual abuse situations during assessments. Results showed that generalization of skills to the natural environment occurred for three of five participants following one to two in situ training sessions, while other participants required many more in situ training sessions to successfully demonstrate the targeted sexual abuse prevention skills. In terms of maintenance, three of four participants who were assessed one month following training maintained the skills, and two maintained the skills at the three-month follow-up. Results from the follow-up assessment suggest that it may be important to conduct in situ assessments at periodic intervals following training and to provide in situ training as needed to help maintain the safety skills.

In situ training clearly enhances the effects of BST; however, a paradox exists for teaching safety skills such as pedestrian safety because "in-situ" training, which would best promote skill generalization, is inherently dangerous for the learner and logistically difficult for the educator (i.e., arranging a naturally occurring situation while providing enough fail-safes to ensure safety). One means to resolve the paradox and make in situ training safe is to use newly developed technology such as a virtual training environments for in situ training. Virtual environments can closely mimic the real world without the potentially disastrous consequences associated with unsafe behavior (e.g., collision when crossing in front of a car).
Virtual Reality (VR)

Grigore Burdea, a leading VR researcher and author of several texts on the subject, defines VR by its functionality. His definition notes that VR is a simulation that uses computer graphics to create realistic-looking worlds (Burdea & Coiffet, 2003). Most notably, these worlds are not static. Rather, they respond to the user's behavior (i.e., input) in real time. This produces VR's characteristic interactivity. As the level of interactivity increases, a feeling of immersion is created for the user. Coupled with the human imagination, the interactivity and immersion of VR has led to solutions to real problems in engineering, medicine, military work, and applied psychology.

Although the average citizen may view VR as a new field, the technology and science date back more than 40 years when, in 1962, a U.S. Patent was issued to Morton Heilig for his invention entitled Sensorama Simulator (Burdea & Coiffet, 2003). This was the first VR video arcade, which had 3-D video feedback (obtained with a pair of side-by-side 35-mm cameras), motion, color, stereo sound, aromas, wind effects (using small fans placed near the user's head), and a seat that vibrated. These components combined to provide the user with a somewhat realistic experience of riding a motorcycle. The “rider” could sense the wind and feel the potholes of the road as the seat vibrated. Heilig also conducted early work to develop head-mounted displays (HMDs), which provided an alternate means for the user to see and experience the VR world. This line of research was further developed when Ivan Sutherland continued Heilig's work in the 1960s with the realization that he could use computer-generated scenes instead of analog images taken by cameras. They began to design a scene-generating device, which was the precursor of the modern VR graphic accelerator.
With the military and NASA taking an interest, research moved headfast into the 1970s and 1980s. In 1981, NASA created the prototype of a liquid crystal display (LCD)-based HMD, which they named the Virtual Visual Environment Display (VIVED). The majority of today's HMDs still use the same principles in their design. NASA scientists proceeded to create the first VR system by incorporating a host computer, a graphics computer, and a noncontact tracker. In 1985, Scott Fisher joined the project and integrated a new kind of sensing glove into the simulation. The 1980s and 1990s continued to focus on VR research. The first company to sell VR products was VPL Inc. Until 1992 this company produced the only commercially available sensing glove. Nintendo then introduced a much cheaper version, the PowerGlove, and the field continued to grow in popularity.

Despite the increased interest and research gains, the market was small and VR research remained a costly endeavor well into the 1990's (Burdea & Coiffet, 2003). The field of VR experienced a rebirth in the mid-1990's when large-volume displays were introduced. These displays were capable of much larger images than those available on even the most modern HMDs. With wall-size images, more users could participate in the same simulation, and the VR market moved from just 50 million dollars in 1993 to 500 million dollars in 1996, and 1.4 billion dollars by 2000 with expectations for continued market growth (Burdea & Coiffet, 2003).

Modern day VR is characterized by the five classic system components: the VR engine, software, input/output (I/O) devices, the user, and the task (Burdea & Coiffet, 2003). In this system, the engine refers to the computer, the software refers to the tool used to render the virtual world, and input devices refer to mice, joysticks, keyboards,
and similar components. Output devices refer to the visual displays necessary for the user to see the virtual world. The group of output devices is quite large and consists of HMDs, hand-supported displays (e.g., virtual binoculars), floor-supported displays which use an articulated mechanical arm to offload the weight of the graphics display from the user, and desk-supported monitors. The use of large volume displays allow several users who are located in close proximity to each other to simultaneously view virtual worlds. These may be presented as single or side-by-side monitors or projector-based displays such as caves, display walls, and domes.

Years of advances in computer science have resulted in affordable VR technology that allows the experience of behavior and exploration in a three-dimensional, computer-generated world that is responsive to the user (Negroponte, 1995). Although the user can experience virtual environments in numerous ways, the most readily available VR platform today is the computer-based desktop environment commonly experienced in 3-D video games (Rheingold, 1991). Until recently, the usefulness and realism of present-generation VR simulators was hampered by a lack of force and tactile feedback to the user (Burdea, 2003). This resulted in more difficult navigation through virtual worlds and difficulty with grasping and manipulating objects. However, devices capable of providing very useful sensory feedback now exist, and force feedback (i.e., sensation of weight or resistance) is currently the most popular. Force feedback requires a device, which produces a force on the body equivalent or scaled to that of a real object to allow a person in cyberspace to feel the weight of virtual objects or the resistance to motion that they create (Burdea, 1996). With continued technological advances such as force feedback
Therapeutic Application of VR

Therapeutic applications of VR have been documented for a variety of clinical populations. VR has been incorporated into exposure therapy for specific phobias (Botella et al., 2006; Rothbaum et al., 1995; Pyne, 1994), as an adjunctive treatment of pain during wound care for burns (Hoffman et al., 2004), to assist in mastery of wheelchair use for children with cerebral palsy (Ira, 1997), to restore skilled movement for children recovering from traumas and diseases (Andrae, 1996; Kuhlen & Doyle, 1994; Latash, 1998; Rose, Johnson, & Attree, 1997), as a tool for systematic assessment and treatment for stuttering (Brundage, 2007), to assess functional communication in aphasia (Garcia, Rebolledo, Metthe, & Lefebvre, 2007), to teach social skills (Mitchell, Parsons, Leonard, 2007), and to improve safety skills (Padgett, Strickland, & Coles, 2006).

Two of the most frequently assessed and/or treated safety skills in VR research are pedestrian safety and fire safety. In 2002, McComas, MacKay, and Pivik evaluated a desktop VR program on knowledge of pedestrian safety skills in the virtual environment and whether new knowledge in pedestrian safety would transfer to real world behavior. Following focus groups with a number of key experts, a virtual city with eight interactive intersections was developed. Ninety-five children participated in a community trial from one urban and one suburban school. Approximately half were assigned to a control group who received an unrelated VR program, and half received the pedestrian safety VR intervention. Colored backpack tags identified group designation and actual street
crossing was observed one week before and one week after the interventions. Significant changes in performance were observed after three trials with the VR street crossing intervention. Children learned safe street crossing within the virtual environment and transfer was observed for suburban school children but not urban school children.

In 2004, Boian, Burdea, Deutsch, and Winter presented preliminary data for a mobility simulator used in the gait rehabilitation for individuals post-stroke. While improving physical strength and abilities, the presentation of a naturalistic context requiring movement (i.e., street crossing) afforded patients the opportunity to improve their safety skills in addition to their physical skills. The virtual environment mobility simulator used two Rutgers Mega Ankle (RMA) robot prototypes, a PC rendering the simulation, a large display showing the virtual scene, and an unweighing frame. The simulator was designed for training while standing in a realistic setting of a street-crossing environment. Therapists could change the difficulty of the task in the simulated environment by manipulating a set of variables such as street width, the duration of pedestrian green light, the level of environmental distractions (visual and auditory), as well as the road surface and visibility conditions. During rehabilitation sessions, the patient stood with each foot secured to the top of one RMA robot while facing the virtual scene. The RMAs provided haptic feedback actuated by compressed air to simulate walking. The process was similar to walking on a treadmill with the major difference that the RMA robots could be programmed to apply haptic effects simulating various surface conditions. VR scenes alternated between rural and urban, and weather conditions changed from icy road surface in winter to a muddy crossing at night. While the goal of this study was to improve gait rather than pedestrian safety skills, which the researchers
were able to accomplish, the research highlights the level of realism that can be produced via creative use of VR interface devices and modified simulation features of virtual pedestrian environments.

In 2006, Clancy, Rucklidge, and Owen published data on an immersive VR traffic gap-choice to determine whether ADHD adolescents show more unsafe road-crossing behavior than controls. The aim of the study was to assess, rather than teach, pedestrian safety in this population. Forty-eight individuals were divided into two groups with females representing half of each group. Participants did not take stimulant medication on the day of testing and had a lower margin of safety, walked more slowly, underutilized the available gap in incoming traffic, showed greater variability in road-crossing behavior, and evidenced twice as many collisions as compared to the controls.

With each new study, more is learned about how virtual environments should be arranged to promote skill acquisition, how children respond to the virtual world, and about the feasibility of interventions of this nature. In spite of the therapeutic advances made thus far, limited research has been published wherein the therapeutic use of VR is evaluated with children with ASDs. Dorothy Strickland published the first study in the psychological literature that included children with ASDs (Strickland, Marcus, Mesibov, & Hogan, 1996) as the first examination of whether children and adolescents with an ASD could tolerate VR environments. The authors published two case studies examining whether children with autism would tolerate wearing VR equipment and could respond to the computer-generated world in a meaningful way. Wearing an HMD, a 7-year-old female and 9-year-old male participant were asked to walk within the virtual environment, verbally identify cars and their color appearing in street scenes, and locate
and walk toward a specific object. Each child was successful with these tasks indicating that they were able and willing to accept and interact within virtually created worlds.

Max and Burke (1997) evaluated (a) whether children could interact with virtual environments for longer periods of time, ignore a variety of distracters and acquire skills, and (b) which sensory components of VR were appealing. Although durations varied, participants tolerated sessions up to 11 minutes successfully with improved attention and performance across sessions. Age was not a predictor of performance. When attending, children appeared focused and their bodies remained at rest. Sight and localized sound attracted attention to events and locations in the virtual environment. Children were drawn to more complex visual and auditory events and preferred listening to louder rock music as compared to softer chorale music.

A third investigation of the feasibility of VR with individuals with ASD was conducted by Parsons, Mitchell, and Leonard (2004) who used a virtual café environment created and presented via desktop computer. This study assessed time spent completing various tasks, errors made during task completion, basic understanding of the representational quality of virtual environments, and the social appropriateness of performance for 12 children and adolescents diagnosed with an ASD and an IQ of 70 or higher. Researchers found that the performance of the participants was comparable to their matched, non-ASD counterparts, and there was evidence that the majority of the participants had a basic understanding of the representational nature of the virtual environment. However, some participants were significantly more likely to bump into, or walk between other people in the virtual scene compared to their matched counterparts. Despite this difference, this study provides additional evidence that children and
adolescents with ASDs can tolerate exposure to virtual environments and have the ability to interact with the technology in a meaningful way. Together, these three studies provide preliminary support for the potential of VR interventions with children with ASDs.

Three additional publications include individuals with an ASD as participants in studies designed to evaluate the potential therapeutic effects of VR based teaching tools. In 2005, an exploratory empirical study determined if individuals with autism could identify and make inferences from a humanoid avatar's facial expression (Moore, Cheng, McGrath, & Powell, 2005). Thirty-four school-aged children and teenagers with autism participated in the study. Over 90% of the participants accurately recognized emotions, leading researchers to conclude that integrating avatars with emotion shifting capabilities into collaborative virtual environments offered an advantageous learning environment for the advancement of social behavior.

In 2007, Self, Scudder, Weheba, and Crumrine published data that compared benefits of VR treatment versus an integrated treatment model (visual learning strategies, role-play/rehearsal, visually structured directions, comic book conversations, etc.) when teaching safety skills to children with ASD in a public school setting. The VR condition used a laptop computer, a separate flat panel monitor, a Scent Palate® to create a smoke scent, and a mouse as the interface. Participants were eight children diagnosed with ASD who were randomly assigned to treatment groups to learn fire and tornado safety skills. The two training conditions were compared to determine whether the use of VR would be as effective and efficient for training safety skills as the integration of multiple visually structured teaching strategies. Both groups improved their learning, and transfer of safety skills to real life situations was achieved. However, the VR group was able to do so in
considerably less time. While the results appear to support the use of VR as a therapeutic tool for this population, the limitations inherent in using 2 groups with only 4 participants each, with no crossover design, should result in cautious interpretation of the results.

Also in 2007, Mitchell, Parsons, and Leonard published data for four male and two female teenagers with ASDs who were taught social skills applicable to selecting a seat in a public place (i.e., café, bus). Following exposure to a virtual café, with built-in performance feedback for all four levels of design and different learning tasks associated with each level, participants were shown video clips of a real café and the interior of a bus. They were asked where they would sit and why to assess whether judgments and explanations changed in a way that indicated improved social understanding after using the virtual café. The results from ratings of participants’ choices of where to sit in videoed scenes and their accompanying reasoning suggest that at least some benefited from the experience with the virtual environment.

The benefits and potential applications of VR for children and adolescents with ASDs may be quite substantial but need to be further demonstrated empirically. Perhaps one of the most notable benefits is that VR affords incomparable control over the environment, allowing researchers and clinicians to arrange environments to best promote learning and generalization. Access to VR equipment and a knowledgeable programmer can allow removal and gradual introduction of distracting stimuli, exaggeration and gradual return to normal of salient stimulus features, and limitless creation of training exemplars to promote generalization. Another notable advantage is that it may offer a highly realistic but safe environment in which to teach skills that are associated with some level of danger (e.g., pedestrian safety, stranger safety, etc.) when
taught in the natural environment. The current drawbacks to VR are cost, programming requirements, and general lack of availability to clinicians and most researchers. However, technological advancements and the production and marketing of lower-cost systems are making VR available as an invaluable tool to the behavioral clinician and researcher.

**Blending Behavioral Technology and VR Technology**

With evidence that children with ASDs are in need of safety skills training and that the currently accepted best-practice intervention (i.e., BST) requires in situ training to provide the best treatment gains, researchers and clinicians must be willing to delve into new territory. Based on the current state of the literature, VR is the most promising component for creating an ideal in situ environment for safety skills training and may provide a valuable enhancement to BST. This infusion of technology is a natural extension of work conducted as early as 1988 when Poche, Yoder & Miltenberger incorporated video to enhance BST for teaching children abduction safety skills.

Individuals with ASDs have persistent learning problems due to ineffectively attending to their environment and generalization failures (Mesibov, Adams, & Klinger, 1997), and often need additional learning trials and more specially structured learning environments compared to their typically developing counterparts. Notable salience of stimuli is key in providing an optimal learning environment for children with ASDs and gradual addition of realistic distracters is key in promoting generalization of the learned response (Heflin & Alberto, 2001). VR technology can achieve these ends because it affords incomparable control for arrangement of environments that best promote learning and generalization (e.g., removal and gradual introduction of distracting stimuli,
exaggeration and normalization of critical stimulus features, and creation of limitless training examples to promote generalization). Perhaps the most notable advantage of VR is that it may offer a highly realistic but safe environment in which to teach skills that are associated with some level of danger when taught in the natural environment (e.g., pedestrian safety).

With evidence that children with ASDs are in need of safety skills training and that the currently accepted best-practice intervention for skills acquisition across populations, BST, requires in situ training to provide the best treatment gains (Haseltine & Miltenberger, 1990; Miltenberger et al., 1999; Himle et al., 2004; Miltenberger et al., 2004), researchers and clinicians must be willing to delve into new territory to create realistic rehearsal environments that are safe for the user. VR can provide a safe rehearsal environment and may prove useful if the skills acquired in the analog environment are demonstrated in natural environments; however, research to date has provided limited support for using VR as a tool to promote skill acquisition in an ASD population (Self et al., 2007; Mitchell et al., 2007). Given the paucity of research in this area, the primary purpose of the current study was to evaluate the effectiveness of a VR-enhanced BST package for teaching street crossing skills to children on the autism spectrum. Not only is the literature on using VR to teach functional skills to ASD children lacking with only two published reports (Self et al., 2007; Mitchell et al., 2007), there is no published literature which uses VR as a teaching tool within a BST framework. In fact, there is only one published study that uses BST for skill acquisition research with children on the autism spectrum (Stewart, Carr, & LeBlanc, 2007). Therefore, the current study evaluated a VR enhanced version of BST for teaching safe street-crossing skills to individuals with
ASDs. The first two components of BST, instructions and modeling, occurred using traditional didactic techniques. The remaining two phases (i.e., rehearsal and feedback) occurred in a partially immersive virtual environment. Participants navigated situations in the virtual environment and received specific, realistic consequences for their actions accompanied by instructional feedback.

METHOD

Participants

Children between the ages of 9 and 15 diagnosed with ASDs were recruited from local schools, parent organizations, and mental health care providers and via local newspapers. Later elementary and middle school children were targeted because these individuals are more likely to interact in social and community activities and settings that call for the use of safe street crossing behavior with a strong demand on growing independence. See Appendix A for the recruitment announcement read at organization meetings and printed in agency newsletters, Appendix B for the advertisement posted in the local newspaper, and Appendix C for the distributed recruitment flyer. Appendix D provides the content of ongoing contact with parents/guardians who called to express interest in participating. After obtaining consent and assent (see Appendices E and F), participants were screened with respect to demographics, previous safety skills training, prior experience with multimedia equipment, and suitability for the study (see Appendix G for demographic and screening form and Appendix H for a sample script for presenting the screening results to parents).

All participants met the following eligibility criteria. Participants were diagnosed with a Pervasive Developmental Disorder according to DSM-IV-TR criteria (APA, 2000)
and/or classified as Autistically Impaired (AI) according to Michigan educational
guidelines (R 340.1715: MI DOE, 2004) prior to entering the study. Either the Gilliam
Autism Rating Scale (GARS; Gilliam, 1995) or Gilliam Asperger's Disorder Scale
(GADS; Gilliam, 2001) was administered to confirm symptoms unless results from the
prior 6 months were available. For the GARS, the coefficient alpha of the Autism
Quotient is 0.96 and test-retest reliability is \( r = 0.88 \). For the GADS, the coefficient alpha
of the Asperger's Disorder Quotient is 0.94 and test-retest reliability is \( r = 0.93 \). A
structured direct observation assessment, the Autism Diagnostic Observation Schedule
(ADOS; Lord, Rutter, DiLavore, & Risi, 2002) Module 3, was also conducted with each
participant. The ADOS is a semi-structured, standardized assessment of communication,
social interaction, and play or imaginative use of materials with test-retest reliability
coefficients ranging from 0.83 to 0.97 and acceptable validity (Lord et al., 2002). All
participants met cut-off scores for Communication + Social Interaction Totals that would
place them on the autism spectrum.

Additionally, based on findings from Parsons, Mitchell, and Leonard's 2004 study
that higher IQ score increased the likelihood of successful, meaningful interaction within
a virtual space, participants were screened for Full Scale and Verbal IQ scores of 70 or
higher using the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) or
detailed report from prior administration of a similar measure. The WASI is a brief
measure of intelligence for individuals aged 6 to 89 that is nationally standardized and
yields the three traditional Verbal, Performance, and Full Scale IQ scores. According to
the manual, the WASI is appropriate for screening, estimating IQ when a full evaluation
is not possible, reevaluations when time is limited, research estimates of IQ, and other
situations when a more comprehensive evaluation is not needed or not possible.

Corrected split-half reliabilities are presented for all tests and composites for all age levels and most appear quite acceptable, ranging from 0.81 to 0.98 for the subtests, and 0.92 to 0.98 for the IQs. In terms of validity, the correlations between same-named subtests and scales on the WASI and WAIS-III are moderate to high (0.66-0.88 for subtests; 0.76-0.92 for IQs). The WASI has been validated with children with ASDs (Minshew, Turner, Goldstein, 2005).

Five children and adolescents participated in this study. Steven was an 11 years old male with a school classification of AI and a score of 87 on the GADS indicating a high probability of Asperger's Disorder. On the ADOS, he met the cut-off for autism, and on the WASI, his Full Scale score was 78, with a Verbal score of 72. Trish was 11 years old and classified as AI through her local school. Her GARS score of 87 indicated a very likely probability of autism, and her behavior during the ADOS resulted in her meeting the cut-off for autism. Trish’s Full Scale WASI score was 88, and her verbal score was 97. Ethan was a 9 years old male diagnosed with Autistic Disorder. He scored an 89 on the GARS, indicating a very likely probability of autism. On the ADOS, he met the cut-off for autism. His WASI Full Scale score was 97, and his Verbal score was 80. Eve was a 13 years old female with a diagnosis of Asperger’s Disorder. She scored a 125 on the GADS indicating a high probability of Asperger’s Disorder, and she met the cutoff for autism spectrum on the ADOS. Upon entering the study, Eve provided WASI scores indicating a full scale IQ of 99 with a Verbal score of 90. The last participant, Colleen, was a 13 years old female who was diagnosed with Pervasive Developmental Disorder Not Otherwise Specified. She scored a 113 on the GADS indicating a high probability of
Asperger's. On the ADOS, she met the cut-off for autism. Upon entering the study, Colleen provided prior WISC-IV results indicating a full scale IQ of 84 with Verbal Comprehension of 96.

Setting and Materials

All pre- and post-treatment sessions and probe sessions occurred outside in two restricted traffic areas on Western Michigan University's campus. See Appendix I for photographs of the primary street crossing location. All other sessions were conducted in 7.5'x 11.5' therapy rooms equipped with mounted video cameras to record each session for later data scoring and researcher training. The therapy room contained a stand to hold the joystick, a blank wall for projection purposes, chairs for both the researcher and participant, and a computer cart equipped with a computer, speakers, and an LCD projector. No extraneous stimuli (e.g., toys, noise, and objects other than the training materials) were present. The VR program, created using EON Studios software, ran on a personal desktop computer with the display projected onto a white wall, and a Sidewinder Force Feedback 2 joystick from Microsoft used as the interface device.

Experimental Design

A nonconcurrent multiple baseline design across participants was employed to demonstrate experimental control in the virtual environment. This design uses staggered lengths of baseline data collection to control for historical and maturational confounds while replicating treatment effects across participants. Additionally, a within subject repeated measures design was used to determine the effects of training on skills in the natural environment sessions. Graphs were visually inspected for data analysis.
Measurement, Interobserver Agreement, and Procedural Integrity

Trained data collectors scored each participant’s performance during all phases of the study. Before collecting data, each observer participated in training consisting of instruction regarding operational definitions and direct practice at scoring sample videos. Each observer achieved 100% agreement with scoring templates for two training videos created by the experimenter before collecting data for the study. Each training video consisted of trials from each of the study’s phases. For procedural integrity, observers achieved 100% agreement with two scoring templates created by the experimenter before using a structured data sheet and a pre-formatted Microsoft Excel worksheet to record key therapist behaviors corresponding to each component of BST.

The primary dependent measure was the number of observed steps associated with safe street crossing. The instructional sequence of steps used for participant training varied from the sequence of steps coded for data collection. This was due to the fact that step 1 for the participant was to use the crosswalk; however, scoring criterion required that the participant remain within the boundaries of the crosswalk for the duration of crossing, which could only be coded once the participant reached the opposite side of the street. Therefore, what was considered step 1 from the participant’s perspective was coded as step 4 for data collection purposes. For data collection, the complete step sequence was as follows: (1) stop and wait a safe distance from the curb, (2) look left and right for cars, (3) walk and continue looking, and (4) use the crosswalk. Step 1 was scored as correct for in-situ trials if the participant stopped and waited at least 4 inches away from the edge of the sidewalk with his/her body oriented towards the street. For VR trials, the step was scored as correct if the participant stopped on the street-side of the sidewalk with his/her
body oriented towards the street. Step 2 was scored as correct if, while stopped, the participant looked left and right in the direction of potentially oncoming traffic and continued to do so until all traffic had passed. Step 3 was scored as correct if, the child walked forward continuously while looking left and right (in the direction of potentially oncoming traffic) at least one time per lane. Step 4 was scored as correct if, while crossing, the participant remained within the designated crosswalk at all times. If the trial was aborted by the therapist or ended because of a participant-car collision, the step was scored as correct if the participant was within the boundaries of the crosswalk from the beginning of crossing until the time that the trial was terminated.

Each VR rehearsal trial was also coded according to whether the participant ‘Made It Across’ (i.e., the participant maneuvered him/herself from one side of the street to the opposing side, regardless of whether the participant made a mistake or experiences a “close call”), the therapist ‘Aborted’ (i.e., therapist ended the trial before the participant was able to maneuver him/herself to the other side of the street), or a ‘Collision’ took place (i.e., the participant collided with a moving vehicle). Additionally, data collectors noted (a) unusual or problematic behaviors that were observed during street-crossing, (b) comments that the participants made over the course of training, and (c) how many models were embedded in the rehearsal phase for each participant. See Appendix J for a sample data sheet.

A second independent trained observer scored at least 50% of in situ and VR trials for each participant. A trial was scored as an agreement if all four steps coded by one observer were coded identically by the second observer (i.e., all steps matched for an agreement). IOA for each type of trial (i.e., in situ, VR) for each participant was
calculated by dividing agreements by agreements plus disagreements and multiplying by 100. Overall IOA was calculated for each participant by dividing the total number of agreements across trial types by agreements plus disagreements and multiplying by 100. Overall IOA was calculated for each trial type by dividing the total number of agreements across participants for the designated trial type by agreements plus disagreements and multiplying by 100. Results are summarized in Table 1. Overall IOA was 87.7% for in situ trials and 95.3% for VR trials. IOA for the study (i.e., IOA across all trial types for all participants) was 93.5%.

Table 1. **Interobserver agreement for primary dependent measure across participants and trial type**

<table>
<thead>
<tr>
<th></th>
<th>In Situ Trials</th>
<th>VR Trials</th>
<th>Averages Across Types of Trials for Each Participant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steven</td>
<td>Trials</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>100%</td>
<td>95.5%</td>
</tr>
<tr>
<td>Trish</td>
<td>Trials</td>
<td>87.5%</td>
<td>98.2%</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>92.9%</td>
<td>96.4%</td>
</tr>
<tr>
<td>Ethan</td>
<td>Trials</td>
<td>100%</td>
<td>56.6%</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>100%</td>
<td>95.7%</td>
</tr>
<tr>
<td>Eve</td>
<td>Trials</td>
<td>87.5%</td>
<td>97.0%</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>64.3%</td>
<td>87.5%</td>
</tr>
<tr>
<td>Colleen</td>
<td>Trials</td>
<td>81.3%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>84.6%</td>
<td>100%</td>
</tr>
<tr>
<td>Average Across Participants for Each Trial Type</td>
<td>Trials</td>
<td>90.3%</td>
<td>84.7%</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>87.7%</td>
<td>95.3%</td>
</tr>
</tbody>
</table>
Procedural integrity was assessed for all of the videotaped BST sessions. Procedural integrity was coded for each component of BST: Instructions, Modeling, Rehearsal, and Feedback. Each component was evaluated according to a checklist of therapist behaviors/activities that were required to occur in order for correct implementation of the protocol. Items on the checklist were evaluated, and the observer scored either “Yes” or “No” depending on whether the behavior(s) occurred. Instructions and Modeling were coded after the observer viewed the phase in its entirety; however, the nature of Rehearsal and Feedback necessitated that the observer code trial-by-trial. For Instructions, the researcher was required to (1) provide a rationale, (2) quiz the rationale, (3) describe the steps of safe street crossing, (4) quiz the steps, and (5) probe to make sure that all questions were answered. For Modeling, the researcher was required to (1) provide at least four clear models, (2) make sure that at least two of the provided models were “what not to do,” and (3) discuss each model and answer questions. For Rehearsal, procedural integrity data was collected for each trial within the phase by coding whether the researcher provided the appropriate type of trial. For Feedback, procedural integrity data was collected for each trial within the phase by coding whether the researcher provided praise and/or corrective feedback. See Appendix K for a sample data sheet.

The procedural integrity associated with each component of BST was calculated by dividing the number of correctly implemented therapist activities/behaviors by the total number of desired therapist activities/behaviors and multiplying by 100. The procedural integrity percentage for each participant was calculated by dividing the number of correctly implemented BST components by the total number of components
within BST and multiplying by 100. The percentages for each participant were then averaged to yield the overall procedural integrity for the study.

A second independent observer also scored more than 95% of the sessions and trials previously scored for procedural integrity to determine IOA. For Instructions and Modeling, all therapist behaviors/activities had to be coded as a match between primary and secondary observers for an agreement to be noted for the component. For Rehearsal and Modeling, an agreement was defined as two raters scoring all checklist items identically for each trial. Overall agreement for Rehearsal and Feedback was calculated by using the formula agreements divided by agreements plus disagreements multiplied by 100. See Table 2 for procedural integrity results for each participant. Agreement on integrity data was 100% for all BST components for all participants.

| Table 2. Procedural integrity results for each participant across BST components |
|---------------------------------|---------------|---------------|---------------|---------------|---------------|
|                                  | Steven        | Trish         | Ethan         | Eve           | Colleen       |
| Instructions                    |               |               |               |               |               |
| Procedural Int. IOA             | 100%          | 100%          | No Video      | 100%          | 100%          |
| Modeling                        |               |               |               |               |               |
| Procedural Int. IOA             | 100%          | 100%          | 100%          | 100%          | 100%          |
| Rehearsal                       |               |               |               |               |               |
| Procedural Int. IOA             | 100%          | 100%          | 100%          | 100%          | 100%          |
| Trials Coded for IOA            | 100%          | 98%           | 93%           | 68%           | 100%          |
| Feedback                        |               |               |               |               |               |
| Procedural Int. IOA             | 100%          | 100%          | 100%          | 100%          | 100%          |
| Trials Coded for IOA            | 100%          | 100%          | 100%          | 100%          | 100%          |
**Procedures**

Approximately one to two sessions were conducted each week lasting one to two hours in duration. At least one 10-minute free play break occurred for every hour of session time. Participant involvement ranged from 8 to 15 sessions, with variability accounted for by the individual's progress, level of compliance, and scheduling. See Table 3 for additional details regarding the number of sessions required for each participant to complete the study. The primary phases of the study were: (1) in situ pre-test, (2) exposure to VR equipment, (3) baseline data collection in the virtual space, (4) the instructional phase of BST, (5) the modeling phase of BST, (6) in situ probes, (7) the VR enhanced rehearsal phase of BST with increasing levels of difficulty and distractibility, and (8) in situ post-test.

<table>
<thead>
<tr>
<th></th>
<th>Steven</th>
<th>Trish</th>
<th>Ethan</th>
<th>Eve</th>
<th>Colleen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Screening</strong></td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>In Situ Pre-Test</strong></td>
<td>0.5 (4 trials)</td>
<td>0.5 (4 trials)</td>
<td>0.5 (4 trials)</td>
<td>0.5 (4 trials)</td>
<td>0.5 (4 trials)</td>
</tr>
<tr>
<td><strong>Joystick Training</strong></td>
<td>2.5</td>
<td>1.0</td>
<td>2.5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>VR Baseline</strong></td>
<td>0.5 (4 trials)</td>
<td>1.0 (6 trials)</td>
<td>0.5 (9 trials)</td>
<td>1.0 (11 trials)</td>
<td>0.5 (6 trials)</td>
</tr>
<tr>
<td><strong>Instructions &amp; Modeling</strong></td>
<td>3.0 (25 models)</td>
<td>1.5 (15 models)</td>
<td>1.5 (13 models)</td>
<td>0.5 (11 models)</td>
<td>1.0 (10 models)</td>
</tr>
<tr>
<td><strong>In Situ Probes</strong></td>
<td>1.0 (4 trials)</td>
<td>1.5 (8 trials)</td>
<td>0.5 (4 trials)</td>
<td>2.0 (8 trials)</td>
<td>2.0 (8 trials)</td>
</tr>
<tr>
<td><strong>Rehearsal</strong></td>
<td>5.0 (40 trials)</td>
<td>5.0 (51 trials)</td>
<td>5.0 (74 trials)</td>
<td>2.0 (22 trials)</td>
<td>4.0 (26 trials)</td>
</tr>
<tr>
<td><strong>In Situ Post-Test &amp; Wrap-up</strong></td>
<td>1.0 (4 trials)</td>
<td>1.0 (4 trials)</td>
<td>1.0 (4 trials)</td>
<td>1.0 (4 trials)</td>
<td>1.0 (4 trials)</td>
</tr>
<tr>
<td><strong>Total sessions</strong></td>
<td>15.0</td>
<td>13.0</td>
<td>13.0</td>
<td>8.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>
Pre-Test. Pre-test trials were conducted in the natural environment using scenarios staged to ensure that the target behavior occurred within a relatively naturalistic context. For example, one participant who enjoyed playing video games was told that his preferred game had been borrowed by a friend of the researcher and must be retrieved from the friend who was waiting in the parking lot. As the researcher and participant approached the crosswalk area, the researcher provided an excuse for staying behind: “I see a girl that I know, and I need to ask her a question. See my friend over there? Go ahead and cross the street to get the game from her, and I’ll meet you back here.” A situation of this nature provided four pre-test data points. The participant crossed one street to arrive at a median, and then crossed a second street to arrive at their target destination. The return trip involved crossing the same streets, thereby resulting in a total of four streets being crossed. The trials were repeated following the instructions and modeling phases of BST to determine if these two components were sufficient to produce behavior change.

Trials involved 9-14 assistants: a participant escort, a person with a targeted item to retrieve, one to two trained confederates present to collect data, two to four confederates to ensure the safety of the participants, and four to six confederates to drive vehicles. See Appendix L for a sample map provided for drivers to reference and Appendices M-O for instructions that were provided to the confederates involved in the study. For each staged scenario, at least two trained confederates were positioned on opposite sides of the street. As the child crossed, a confederate crossed the street closely behind the participant. The confederate’s close proximity to the participant allowed him/her to cross safely. If the situation became unsafe, the confederate was instructed to
immediately terminate the trial and remove the participant from the situation. Using a
structured data sheet, one or two additional confederates were present to record whether
each step of street-crossing was performed correctly or incorrectly. Trained research
assistants drove cars in the area to allow for added environmental control necessary to
ensure the safety of the participants.

*Exposure to Equipment.* Each participant learned to operate the interactive
equipment prior to data collection within the virtual space. Two virtual scenes, unlike the
scenes used during later training phases, were created for joystick training purposes. The
first scene included two, wide, intersecting, purple paths with large 3-D shapes at each
end of each path (see Appendix P for a screenshot). The second scene included a brick
sidewalk on a field of green grass. This second scene was created so that participants
could learn to turn around without inadvertently stepping into the grass, which would
translate into skilled turns to avoid stepping into the street during later training trials (see
Appendix Q for a screenshot). Didactic instructions, modeling, and feedback were
provided as needed to ensure that each participant could operate the joystick to turn
around in a small circle, move at varying speeds forward, backward, left, and right, and
look left, right, up, and down. All movements were practiced until the participant could
confidently execute them on command.

*VR Baseline.* Baseline data was collected in the virtual space prior to the
implementation of BST. For baseline trials, the participant was handed a joystick,
presented with the relevant virtual environment (i.e., an environment with one passing car
and minimal distracting stimuli), and told: "This may seem like a video game, but it's not.
In this program, you are supposed to do what you would do in the real world. So, if you
want to cross the street, make sure you do so safely. Today you can be a big help to us by walking around and telling us what buildings you see so that we can make a map of our street. We'll be using this scene later, and it will be helpful to know where buildings are located." No extraneous reinforcement was provided for safe street crossing behaviors. Baseline continued until performance measures were stable and stagger across participants was achieved.

**VR-Enhanced BST.** Treatment consisted of a VR-enhanced BST package. The four primary components of BST were included: (1) instructions, (2) modeling, (3) rehearsal, and (4) feedback. See Appendix R for the job-aid used by researchers during the provision of BST.

First, instructions were provided including a rationale for consistent use of safe street-crossing skills and a precise description of the safety skills. Additional instructional topics included the proper sequence of steps and the appropriate circumstances for use of street-crossing skills. The complexity of the instructions was tailored to the participant's level of cognitive ability and the instructor prompted and praised attending when necessary. Question-and-answer opportunities (i.e., informal quizzing) were embedded to ensure that the participant heard the instructions and remembered them. See Appendix S for visual aids that were used during the instructional phase.

Second, the researcher presented models of the desired behavior to illustrate the specific components of the safety skills. All models took place in the session room. Colored duct tape was used on the floor to represent a street, sidewalks, and a crosswalk. At least four models (i.e., two exemplars, two non-exemplars) were implemented with a range of 10-25 models (see Table 3). Modeling continued if the participant could not
respond accurately to quizzing or if the participant requested additional models. Thus, each participant viewed several, complete models, both appropriate and inappropriate, to enhance discrimination for subsequent skill implementation. Following each model, the researcher and participant discussed the details of the model, including which steps were seen and what the model could have done to improve his/her safe behavior. As in the instructional phase, informal quiz opportunities were used to ensure that the participant was beginning to make discriminations between unsafe and safe behavior.

Rehearsal and feedback occurred together and were conducted in the virtual environment specifically designed for this study. The child could elect to sit or stand while interacting with the virtual space; however, most participants choose to sit. In the upper left corner of the scene was a picture-in-picture window so the user could see his avatar (i.e., computer representation) to allow easier judgment of the distance from the avatar and the edge of the sidewalk. During prior joystick training, participants were taught to periodically reference the picture-in-picture window to gain additional perspective about their position in the virtual space.

Four increasingly complex versions of the virtual space were used. The base VR scene consisted of a single two-lane roadway designed for opposing traffic with parallel parking spaces located on each side. Multiple crosswalks were included such that participants only had to walk a short distance before arriving at a safe street-crossing zone. The base scene also included wide brick sidewalks, commercial buildings, and street signs. There were no moving vehicles or distracting stimuli. The base version was used for preliminary rehearsal opportunities. The second version consisted of the base scene with sound and one of two cars moving at any given time. The third version
consisted of the base scene with sound, moving cars, and additional distracting stimuli while the fourth version consisted of the base scene with sound, distracting stimuli, and cars passing with varying latencies. See Appendix T for a screenshot representing versions 1 and 2 and Appendix U for a screenshot for versions 3 and 4. Once the participant completed at least two consecutive trials with all four steps of safe street crossing successfully exhibited in one version, the next version of the simulation was presented.

Feedback was provided in two forms: (1) immediate feedback from natural consequences, and (2) delayed, person-delivered feedback. In the first form, performance errors resulted in logical consequences within the virtual space including "close calls" with a motor vehicle (i.e., honking) and person-to-motor vehicle collisions with tactile force feedback provided by the joystick, transition to a white screen, and being "timed-out" from interacting with the virtual space for two minutes. In addition, the experimenter provided verbal praise for correctly performed behaviors and corrective verbal feedback for skill components that needed improvement at the end of the rehearsal trial. When corrective feedback was warranted for multiple aspects of the skill, the researcher provided feedback on only one component so as not to overwhelm or discourage the participant with negative feedback.

**Post-Test Evaluation.** In situ post-test evaluation trials were identical to pre-test evaluation trials and probe trials with one exception. The primary researcher did not escort the participants to the street crossing area. Instead, a "friend" of the researcher who seemingly had no affiliation with the study accompanied the participant. This strategy
was used to minimize reactivity that might occur if the primary researcher had become a
discriminative stimulus for safe street crossing behavior.

*Post Treatment Consultation.* At the conclusion of each participant's involvement with the study, researchers met with the participant's parent(s)/guardian(s) to discuss the study. During this meeting, they were reminded that although the study's purpose was to evaluate an intervention for improving safe street crossing behavior, their child's skills may not be sufficient to allow him/her to engage in unmonitored street-crossing. If the participant's data indicated an improvement in street-crossing behavior, this should be seen merely as evidence that continued safety skills training for this target would likely result in continued improvement, which may *one day* lead to independent street-crossing. Researchers also met with each participant, praised them for their performance and participation, and cautioned them against independent street-crossing until they have had the opportunity to engage in more practice with their parents or other educators.

**RESULTS**

Table 3 indicates the number of sessions devoted to each phase of the study for each participant. Screening, in situ pre-test, and in-situ post-tests were consistent across participants whereas the number of sessions for VR baseline and all training phases varied according to the stagger for the multiple baseline design and individual variation in learning for training phases. The three female participants required only one session for joystick training whereas both male participants required at least twice as much training to meet the mastery criterion. The total number of training trials required for each participant to progress through all four versions of the VR rehearsal environment (i.e., the entire rehearsal phase of BST) also varied with a range of 22-74 trials.
Table 4 illustrates the number of training trials required for each participant to master each of the four versions of the VR rehearsal environment while Figure 1 depicts data in a multiple baseline across participants design. No clear pattern emerged across participants with an average of 42.6 trials to criterion and a range of 22 to 74. These results indicate that while all participants required training to move through each version, the unique difficulties inherent in each rehearsal version challenged the participants in different ways.

Table 4. Number of trials required for each participant to master each of the four versions of the virtual reality rehearsal environment

<table>
<thead>
<tr>
<th>Rehearsal Version</th>
<th>Steven</th>
<th>Trish</th>
<th>Ethan</th>
<th>Eve</th>
<th>Colleen</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV1</td>
<td>24</td>
<td>23</td>
<td>19</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>RV2</td>
<td>3</td>
<td>7</td>
<td>18</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>RV3</td>
<td>10</td>
<td>4</td>
<td>34</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>RV4</td>
<td>3</td>
<td>17</td>
<td>3</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>51</td>
<td>74</td>
<td>22</td>
<td>26</td>
</tr>
</tbody>
</table>
Figure 1. Percentage of steps successfully executed in the virtual environment for all participants.
Steven performed poorly ($M = 37.5\%$ accuracy, range = 25-50\%) during in situ pre-test trials (see Figure 2). An error analysis revealed that steps 1 and 3 were the most problematic: step 1 = 100\% errors, step 2 = 50\% errors, step 3 = 100\% errors and step 4 = 0\% errors. Step 4, using a crosswalk and remaining within the boundaries for the duration of the crossing episode, was the only step that was consistently implemented with success. Following instructions and modeling, no increase in performance was observed in the in situ probe trials ($M = 6.25\%$, range = 0\% to 25\%) with a similar error pattern as pre-test: step 1 = 100\% errors, step 2 = 100\% errors, step 3 = 100\% errors, and step 4 = 75\% errors. Instructions and modeling were not sufficient to improve Steven’s street crossing in the natural environment so the study continued with rehearsal in the virtual environment. After meeting the mastery criterion (i.e., three trials with no errors in the fourth version of the VR environment), post-test trials were conducted resulting in an average accuracy of 50\% (range = 25-75\% accuracy). An error analysis revealed that step 4 remained perfect while steps 1-3 showed varying levels of improvement: step 1 = 75\% errors, step 2 = 75\% errors, step 3 = 50\% errors, and step 4 = 0\% errors. When comparing step-specific performance from pre-test to post-test, no notable improvement was seen for Steps 1 and 2. However, for step 3, walking across the street while continuing to look for new oncoming traffic, Steven’s performance improved from 0\% to 50\%. 
Steven's performance in the virtual environment is depicted in Figure 3. During baseline, Steven failed to successfully execute any of the four steps associated with safe street crossing with typical performance errors including crossing without stopping to make sure that there was no oncoming traffic, stopping in the middle of the road, and failing to modify his behavior once he observed that a car was approaching. This final error, which occurred during the fourth baseline trial, resulted in a virtual person-to-car collision. During the 24 training trials in the first VR version, which took the longest to complete, an upward trend was evident though the overall mean accuracy for all trials was modest. The following performances were obtained for each skill step: step 1 = 47.80% of trials with errors, step 2 = 25%, step 3 = 52%, and step 4 = 17%. Common errors included stopping while crossing, failing to wait a safe distance from the curb while looking left and right for cars, and walking into the road backwards. Eight models
were provided to illustrate feedback provided following incorrect trials. In the second VR version, Steven made no errors and progressed to the third version after three perfect trials. In the third version, Steven's performance was more variable but remained above 75% as additional visual and auditory distracters were added. Steven typically independently recognized many mistakes and self-corrected (e.g., correcting drift out of crosswalk) and demonstrated his only mistakes on skill steps 2 (30% with error) and 3 (10% with error) which involved looking left and right for cars in the presence of auditory and visual distracters. In the fourth and final version of the VR environment, three trials were conducted and no errors occurred. Over the course of training, the therapist provided two role-play live models and 10 VR models (third VR environment) to illustrate skills in conjunction with verbal feedback. No person-to-car collisions occurred during training in the VR environment.

Figure 3. Percentage of steps successfully executed in the VR environment for Steven.
Trish

Trish also performed poorly \( (M = 12.5\% \text{ accuracy, range } = 0-25\%) \) during in-situ pre-test trials (see Figure 4). An error analysis revealed a need for improvement across all steps of street crossing: step 1 = 100\% errors, step 2 = 50\% errors, step 3 = 100\% errors, and step 4 = 100\% errors. Following instructions and modeling, in situ probe trials \( (M = 100\%, \text{ no range}) \) indicated a dramatic increase in performance of the four safe street crossing skills. However, Trish’s comments to the researcher indicated that she was acutely aware that her street crossing performance was being evaluated, suggesting a strong observer effect. To minimize reactivity, he researchers conducted training on a “distracter” safety skill—abduction safety and then conducted a second in situ probe with an adult companion who was seemingly unaffiliated with the study. Results (see Figure 4; \( M = 37.5\% \text{ and range is 25\% to 75\%} \)) show a decrease in performance relative to the first in-situ probe. Error analysis revealed the following: step 1 = 75\% errors, step 2 = 50\% errors, step 3 = 100\% errors, and step 4 = 25\% errors. Instructions and modeling were sufficient to teach Trish what she needed to do in the natural environment; yet these phases of BST were insufficient in getting her to successfully execute the steps when she believed that her behavior was not being evaluated. Therefore, the study continued with rehearsal in the virtual environment. After meeting mastery criteria in VR training, an in situ post-test probe \( (M = 81.25\% \text{ and range of 75\% to 100\%}) \) shows a significant increase in performance relative to the pre-test probe. An error analysis revealed the following: step 1 = 0\% errors, step 2 = 0\% errors, step 3 = 75 \% errors, and step 4 = 0\% errors. Comparison with step-specific performance from pre-test to post-test indicates notable improvement for Steps 1, 2, and 4.
Figure 5 depicts Trish's street crossing behavior across all phases in the virtual environment. For the six baseline trials, error analysis revealed that Trish failed to use a crosswalk for 16% of trials and failed all other steps on all six trials. Twenty-three trials were required to meet the mastery criterion for the first rehearsal version. Error analysis revealed the following percentages of trials for which a skill step was not executed correctly: step 1 = 45%, step 2 = 13.6%, step 3 = 22.7%, and step 4 = 9%. Again in this rehearsal version, Trish experienced the most success with step 4 (i.e., using a crosswalk). During this phase Trish's errors included, but were not limited to, stopping while crossing to continue looking left and right rather than incorporating these two behaviors into one fluid movement and failing to wait a safe distance from the curb while looking left and right for cars. Trish mastered the second rehearsal version in seven trials, making only two mistakes. In both cases, she stopped in the street while crossing, thereby
failing to perform step 3 correctly. Despite these errors, her performance never dropped below 75%, and she was observed to self-correct when she recognized that she was making an error. For example, on trial 45, she quickly stopped when an approaching car provided the first warning honk. She remained calm, and simply stated, “I'm waiting for a car to go by so it's safe.” After completing four errorless trials in the third version of the VR rehearsal environment, Trish progressed to the fourth version. Seventeen trials were necessary to meet the mastery criterion and an error analysis revealed errors on: step 1 = 0% of trials, step 2 = 0%, step 3 = 43.7%, and step 4 = 18.4%. The increased speed of passing cars in version 4 resulted in increased anxiety about crossing and attempts to cross more quickly with failure to continuously monitor traffic while crossing. Despite these errors, no person-to-car collisions took place. Over the course of training, the therapist provided one role-play live models and six VR models, all within the first VR training environment, to illustrate skills in conjunction with verbal feedback.

Figure 5. Percentage of successfully executed steps in the VR environment for Trish.
Ethan

Ethan performed poorly ($M = 18.75\%$ accuracy, range = 0-25\%) during in situ pre-test trials (see Figure 6). Error analysis reveals the following percentage of trials for which the skill was not successfully executed: step 1 = 100\%, step 2 = 100\%, step 3 = 100\%, and step 4 = 25\%. Ethan ran across the street for all four trials, and although his verbal behavior indicated that he noticed an approaching vehicle, he did not wait for it to pass before crossing. Following instructions and modeling, four in situ probe trials were conducted (see Figure 6) with the following results: $M = 31.25\%$ and range = 25-50\%. Error analysis revealed high error rates for steps 1-3: step 1 = 100\% of trials with error, step 2 = 100\%, step 3 = 75\%, and step 4 = 0\%. Similar to baseline, only step 4 (using the crosswalk) was executed consistently. Ethan ran while crossing on one trial, skipped across another, and walked across for the other two trials. The performance average for the in-situ probe shows no significant improvement over pre-test in-situ performance indicating that instructions and modeling were not sufficient to significantly improve Ethan’s street crossing in the natural environment. The study continued with rehearsal in the virtual environment. After meeting mastery criteria in VR training, an in situ post-test probe ($M = 43.75\%$ and range of 25\% to 75\%; see Figure 5) shows slight but not significant improvement over in-situ pre-test performance. An error analysis revealed the percentage of trials for which the skill was not successfully executed: step 1 = 100\%, step 2 = 75\%, step 3 = 50\%, and step 4 = 0\%. As during probe trials, Ethan experienced the most success with execution of steps 3 and 4.
Figure 6. Percentage of successfully executed steps in situ for Ethan.

Figure 7 depicts Ethan’s street crossing behavior across all phases in the virtual environment. Ethan failed to consistently execute any of the four steps associated with safe street crossing during baseline: step 1 = 90% of trials with errors, step 2 = 100%, step 3 = 100%, and step 4 = 80%. Ethan had one close call with a vehicle in which he was honked at during this phase. The first VR rehearsal version required 19 training trials with errors as follows: step 1 = 52.60% of trials with errors, step 2 = 42%, step 3 = 47%, and step 4 = 21%. Ethan’s errors included failing to wait a safe distance from the curb, stopping at the curb before entering the street but failing to look to see if traffic was approaching, and stopping just short of reaching the opposite side of the street. Eight models were provided to illustrate feedback provided following incorrect trials. Eighteen trials were required for mastery of the second VR rehearsal version with errors as
follows: step 1 = 22% of trials with errors, step 2 = 22%, step 3 = 66%, and step 4 = 11%.

An initial decrease in performance occurred as rehearsal trials began with the second version because Ethan had great difficulty crossing at a slower pace that would allow him to walk and continue looking left and right for oncoming traffic. Seven models were provided to illustrate feedback provided following incorrect trials, and he was ultimately successful with meeting mastery the mastery criterion. Ethan’s performance decreased when additional distracters were introduced in the third VR rehearsal version; however, he met the mastery criterion after 34 rehearsal trials.

Figure 7. Percentage of successfully executed steps in the VR environment for Ethan.

Error analysis revealed the following percentages of trials for which a skill step was not executed correctly: step 1 = 8%, step 2 = 2.9%, step 3 = 47%, and step 4 = 5.8%. These data indicate that when additional distracters were added, Ethan’s ability to look
left and right for cars while crossing at a safe speed was impaired. Five VR models were provided to illustrate what the therapist was attempting to convey during the provision of verbal feedback following a trial where skills steps were not executed successfully. No person-to-car collisions occurred during any version of the rehearsal environment. Ethan was able to progress through the final VR rehearsal environment in only three trials.

Eve

Four in situ pre-test trials were conducted with Eve resulting in poor accuracy ($M = 18.75\%$ accuracy, range = 0-75%; see Figure 8). An error analysis revealed that errors occurred on most trials for most steps: step 1 = 75\% of trials with errors, step 2 = 25\%, step 3 = 100\%, and step 4 = 75\%. Following instructions and modeling, four in situ probe trials were conducted with significantly improved performance ($M = 87.5\%$ accuracy, range = 50-100\%; see Figure 8). This improvement indicated that instructions and modeling were sufficient to improve Eve’s street crossing in the natural environment; however, to rule out reactivity the distracter skill strategy used with Trish was employed. Eve’s next appointment included instructions and modeling on how to use a map to get from point A to point B by foot and a cover story associated with map following to allow observation of four additional street crossing probes in a secondary street crossing area. The results were comparable to the initial probes ($M = 93.8\%$ accuracy, range = 75\% to 100\% accuracy) with the only errors occurring for failing to stop while looking left and right to determine the safety of crossing. Thus, instructions and modeling were sufficient to improve Eve’s street crossing in the natural environment; however, since any errors could be fatal additional rehearsal in the VR environment began in hopes of increasing consistency of execution of all of the safe street crossing steps. After completing the VR
training, Eve demonstrated consistent success on four in situ post-test trials (see Figure 8). Although Eve's most significant gains occurred following instructions and modeling, additional rehearsal opportunities decreased performance variability and increased proficiency.

![Graph showing performance over trials](image)

Figure 8. Percentage of successfully executed steps in situ for Eve.

Figure 9 depicts Eve's street crossing across all phases in the virtual environment. Eve's baseline data collection was completed in 11 trials with significantly more errors than in the natural environment: step 1 = 90% of trials with errors, step 2 = 54.5%, step 3 = 81.8%, and step 4 = 45%. On the 6th trial, a person-to-car collision occurred. Eight trials were required to meet the mastery criterion for the first rehearsal version with substantially reduced errors: step 1 = 25% of trials with errors, step 2 = 0%, step 3 = 12.5%, and step 4 = 0%. In the second rehearsal version Eve met the mastery criterion...
after 7 trials with few errors: step 1 = 14% of trials with errors, step 2 = 14%, step 3 = 28.5%, and step 4 = 0%. Versions 3 and 4 were completed in 4 and 3 trials respectively with the only error in either phase occurring during the first trial of version 3 when Eve failed to stop before entering the roadway. No models were necessary to supplement verbal feedback and no other person-to-car collisions occurred.

Figure 9. Percentage of successfully executed steps in the VR environment for Eve.

Colleen

Four in situ pre-test trials were conducted with Colleen (see Figure 10) with \( M = 62.5\% \) accuracy and a range of 0% to 100% accuracy. An error analysis revealed the percentage of trials for which the skill was not successfully executed: step 1 = 25%, step 2 = 25%, step 3 = 75%, and step 4 = 25%. Results indicate that improvement with step 3, walking while continuing to look for oncoming traffic, would make the most significant
improvement in increasing Colleen's pre to post-test comparison. During baseline in the VR environment Colleen's performance increased dramatically indicating that joystick training and repeated VR baseline trials may have improved street crossing. Therefore, four in-situ probe trials were conducted prior to the initial phases of BST with similar results to the initial pretest ($M=62.5\%$ and a range of 25\% to 75\%; see Figure 10). Error analysis revealed the percentage of trials for which the skill was not successfully executed: step 1 = 25\%, step 2 = 0\%, step 3 = 100\%, and step 4 = 25\%. Following instructions and modeling, four additional in situ probe trials were conducted with slightly increased performance ($M=75\%$ accuracy, range = 50\% to 100\%; see Figure 10) and the need for further training. An error analysis was conducted and revealed the percentage of trials for which the skill was not successfully executed: step 1 = 50\%, step 2 = 50\%, step 3 = 0\%, and step 4 = 0\%. After meeting the mastery criteria in the VR environment, four in situ post-test trials were conducted with all steps successfully performed in every trial (see Figure 10).

Figure 10. Percentage of successfully executed steps in situ for Colleen.
Figure 11 depicts Colleen's street crossing across all phases in the virtual environment. Colleen's baseline data collection was completed in six trials with very few errors: step 1 = 0% of trials with errors, step 2 = 16.6%, step 3 = 0%, and step 4 = 0%. Colleen progressed through the first, second, and third rehearsal versions in four, five, and three trials, respectively. No models were provided during rehearsal with versions 1 and 2, and two models were provided during rehearsal with version 3. Errors were minimal and occurred during steps 1, 3, and 4. Fourteen trials were necessary for Colleen to progress through the fourth version of the VR rehearsal environment and 11 models were provided.

![Figure 11. Percentage of successfully executed steps in the VR environment for Colleen.](image-url)
An error analysis revealed no errors on steps one and two and errors on step 3 during 50% of trials and step 4 during 28.5% of trials. Although the only modification from version 3 to 4 was a slight change in the timing of cars passing, this was sufficient to result in increased anxiety about crossing. This effect was similar to that observed with Trish and resulted in increased performance errors. On the fourth and sixth rehearsal trials of version 4, person-to-car collisions occurred. Despite the increased difficulty associated with this version of rehearsal, Colleen was able to meet the mastery criterion after repeated practice with feedback.

DISCUSSION

All five participants were able to master all street crossing skills in the virtual environment even with auditory and visual distracters. This supports earlier findings that functional skills can be taught in the context of virtual environments (Mitchell et al., 2007; Self et al., 2007; Padgett et al., 2006; McComas et al., 2002). With appropriate training, even the youngest and most distractible child, Ethan, was able to master use of the joystick and operate effectively in the virtual environment, thereby supporting existing research which indicates that early elementary-school-aged children are suitable for inclusion in VR studies in that they have proven they can effectively interface with VR environments (Strickland et al., 1996).

While the effects in the VR environment were quite good, there were mixed findings regarding the clinical effectiveness of VR-enhanced BST on street crossing in the natural environment. That is, the skills acquired in the VR environment did not uniformly generalize to the natural environment. Colleen and Eve both showed improvement as consistently accurate trials were not observed until post-test following
the VR enhanced BST. Ethan and Steven made modest gains following VR training and Instructions and Modeling seem to have been the most influential components in improving Trish's execution of safe street crossing skills. Given the mixed results for these participants, it is worth considering why more robust findings were not observed. The published data on VR-based interventions with children with ASDs is quite sparse and differences in methodology make it somewhat difficult to compare these results to prior studies. The Mitchell et al. (2007) study, which targeted seat selection skills, did not test skill use in the natural environment following VR training. Similar limits to generalization may or may not have been evident if skill use had been tested in the natural environment. On the other hand, Self et al. (2007) conducted post-treatment in situ assessment and observed successful transfer of safety skills (fire and tornado) to the real world. However, they failed to conduct probes during training to determine when this effect was achieved and whether the in situ rehearsal trials conducted prior to post accounted for the benefits rather than the VR training.

*Stimulus Generalization*

Although the current study attempted to create a virtual world comparable to the naturally occurring street crossing environment, failure to observe the desired generalization from VR to in situ trials suggests that generalization technologies were not as well designed as originally intended. Baer, Wolf, and Risley (1968) noted that 'behavior change may be said to have generality if it proves durable over time, if it appears in a wide variety of possible environments, or if it spreads to a wide variety of related behaviors' (p. 96). A primary purpose of the present study was to teach a skill in one environment (the virtual world) and see effects in a different environment (the real
world). Several strategies outlined by Stokes and Baer's seminal article on generalization (Stokes & Baer, 1977) were incorporated to move beyond the "train and hope" default. A high quality instructional intervention (i.e., BST) was used, and training occurred across exemplars (i.e., various versions of the rehearsal environment) with programmed common stimuli (i.e., stimulus components occurring in common in both the training and generalization setting). Additionally, it was hoped that the gradually increasing difficulty associated with the four versions of the VR rehearsal environment would promote generalization of skills, as it was believed that the more advanced versions more closely approximated conditions of real-world street crossing.

Despite these strategies, there were differences across the two environments, some of which were not anticipated in the design of the study. As a result of these differing stimulus features, consistency in the perceived danger of each situation was not achieved. Rather, the perceived danger associated with the VR street crossing context appeared, based on participant's comments, greater than that associated with the real world. This issue is important because the more perceived risk inherent in a situation, the more vigilant individuals are about executing safe behavior. In other words, the immediate response-contingent prevention of an aversive condition results in an increased frequency of that response. If the participant does not believe that an aversive condition exists, there is no need to engage in the behavior needed to sustain the avoidance contingency. To illustrate this point, the reader is asked to consider typical behavior when parking a car in two distinct locations. If parking in a suburban area that is known for low crime rates and a strong sense of community, one might elect to leave the car doors unlocked. However, if parking on a street in a high crime, urban area, it is
likely that valuable possessions would be removed from the car and the doors securely locked before leaving the vehicle unattended. Similarly, perception of danger is likely to produce greater vigilance with street crossing.

Several participants’ comments support the notion that they were more alert to the negative consequences of unsafe behavior in the VR environment as compared to the in situ environment. Steven’s comments clearly reflect this position. When additional auditory distracters were added to the VR training environment, he asked, “Why did you have to turn on the voice?” and went on to declare, “I don’t want to be run over. A car is going to run me over!” Colleen very clearly articulated, “I’m scared! I don’t want to get hit again,” and provided additional insight into her emotional state by informing the researcher, “I don’t think I can do this. I’m nervous.” Ethan’s comments provide clear evidence for his understanding of the negative consequences of safe street crossing behavior. He stated “I hate the cars. I can’t do this. I’ll get squished. It’s too dangerous” (Eve stated, “This is hard,” and clarified by stating, “This is much easier to do on my own.”)

In contrast, no participant made any similar statements about the natural environment crossings.

The specific stimulus features resulting in the discrepancy in the perceived danger from VR to in situ environments remain less clear. The width of the road and speed of the cars may have contributed. In the VR environment, the road was two wide lanes bordered by parallel parking spots. For in situ trials, participants typically crossed one, single-lane street for each trial. Crossing a greater expanse means more time in the area where cars pass, and therefore greater risk to the individual crossing. Additionally, cars in the VR training environment were traveling at speeds faster than the speed limit for on-campus
traffic, and since both the primary and secondary street crossing locations were on a university campus, researchers were prohibited from increasing the speed of the cars in the in situ trials to more closely approximate the speed of traffic within the virtual training environments.

An additional variable that may have contributed to the decreased generalization by virtue of impacting the level of perceived danger during in situ trials was the presence of safety monitors. Given the researchers' desire to maintain the safety of the participants, as well as the desire to meet HSIRB standards for research, it was necessary to have confederates in place as safety monitors. While the addition of these individuals served to decrease the researcher's concern about accidental injury during in situ trials, it may have resulted in a decrease in perceived danger. It is typically the case that when an adult and child are present, and safety concerns arise, the adult acts swiftly and proactively such that danger can be avoided. It is not uncommon for children to default to letting the adult assume responsibility in this manner, and given this history of child-adult interaction, it is not unreasonable to assume that participants felt more secure with an adult crossing closely behind them, regardless of the adult's affiliation with the study.

Response Generalization

An additional hypothesis regarding why limited gains were seen from pre to post-test pertains to response generalization (i.e., effects of training one behavior spreading to other, often related, behaviors). In this study, it was hoped that response generalization would be observed as participants moved from VR training to in situ assessment. In the virtual environment, all reinforced responses were created by virtue of interacting with the VR interface (i.e., the child remained stationary while fine motor manipulations of the
joystick resulted in movement within the street crossing scene). However, in the real world, the target responses were created by virtue of gross motor movements. Given the lack of observed response generalization, it may be the case that engaging in physical practice (i.e., using an interactive apparatus that would allow for left and right head turns as well as feet movement) would be beneficial.

**Competing Contingencies**

The existence of competing contingencies may also have contributed to the limited improvement in street crossing (i.e., pre-test to post-test) for some participants. As a key component of the behavioral contingency, establishing operations (EOs) present during training and assessment warrant discussion. The term EO was originally defined by Keller and Schoenfeld (1950) as a variable that momentarily alters the reinforcing effectiveness of some other object or event, and Michael (1982; 1993) popularized the term by distinguishing between the discriminative and motivational properties of antecedent events and offering the term EO as a functional descriptor for the latter type.

In the present study, it appeared that there were numerous naturally occurring contingencies, and associated EOs, competing with the child's motivation to engage in safe street crossing behavior. For example, for Colleen, it appeared that the EO for safe street crossing competed with the EO for orienting herself to observe a small animal. Although it did not appear that this competing contingency and associated EO were strong enough to abolish the EO for safe street crossing, that was not the case for the competing contingencies that the researcher inadvertently created. In an effort to motivate the participants to separate from their parents and run an errand with another adult who was seemingly unaffiliated with the study, a cover story was created. More often than
not, the cover stories centered around the child getting access to a highly preferred item. It is reasonable to conclude that this cover story may have established a contingency involving avoidance of the loss of a reinforcer, wherein crossing slowly and conscientiously to promote use of their safe street crossing skills would result in less time to engage in the preferred activity. Desire to play with the preferred item for which access was restricted between sessions may have resulted in an EO that was powerful enough to directly abolish the EO for safe street crossing, if one previously existed. These types of competing EOs are real, common, and meaningful contributors to unsafe behavior in the natural environment. Although not purposefully contrived in the present study, the presence of the competing EO produced a stringent test of the newly acquired skills.

**Limitations and Future Directions**

In addition to the limitations that have been alluded to in the discussion regarding limited improvement from pre-test to post-test (i.e., failure to create rehearsal opportunities of physical movement, inadvertent introduction of competing contingencies, dissimilarity between the training environment and the real world in terms of speed of cars, width of road, etc.) other limitations are also worth noting.

One limitation of the study is the sub-standard reliability for in situ trials. It should be noted that although two data collectors were present, the one closest to the child scored as primary. If the participant crossed east to west at the primary crossing area with two, one-way streets separated by a grassy median equaling 4 trials during the data collection period, data collector 1 (on the east) would serve as primary for trials 1 and 4, and data collector 2 (on the west) would serve as primary for trials 2 and 3. This resulted in data collector 1 serving as reliability for trials 2 and 3, and data collector 2
serving as reliability for trials 1 and 4. Given the distance away from the participant, it was expected that the reliability data would be lower. Turning one's head to look left and right can occur in a reasonably subtle, yet still effective manner. Such subtlety would make it difficult to see from far away. Additionally, step 2 (stopping and wait at the curb) was coded as correct only if the participant was at least 4 inches away from the edge of the curb/sidewalk. Again, the distance between the participant and data collector scoring for reliability would make it difficult, if not sometimes impossible to accurately judge such a precise criterion. Therefore, the unsatisfactory reliability data should not be reason alone to discount the primary data, as increased accuracy was inherent in the contextual arrangement for those data. However, future researchers should be mindful of this limitation and attempt to use additional confederates to ensure that 4 coders are present to collect accurate and reliable data.

Another limitation of the study is the brevity of in-situ data collection. Each phase of in-situ data collection represented one outing from one day, making it difficult to capture naturally occurring variability and more closely examine patterns in responding. Additionally, given that data reflected one outing, all data for each phase was collected in one street crossing location. As with the limited number of trials, the limited location prohibits more specific analysis of the contextual features that may be relevant to skill use across settings. Future research should include additional in situ trials, with trials occurring across street crossing locations, in an effort to collect a more valid sample of the participants' behavior.

Although attempts to control for observer effect by conducting second, modified probe sessions, it is impossible to determine what carryover effects from pre-test and
initial probes had on subsequent data collection. In situ data collection in future research should be more carefully arranged such that observer effects are not an issue.

A final limitation of the study was the failure to identify a more homogenous participant pool. While all participants had an ASD diagnosis with IQ scores above 70, their behavioral presentation was quite different. Steven presented as a “classically autistic” child with notably impaired language and social skills and obvious repetitive and stereotyped patterns of behavior. In contrast, Eve was four years older, well integrated into regular education, and presented with much more subtle skills deficits consistent with Asperger’s Disorder. With a participant pool representing points along the autism spectrum that are quite removed from one another, determining the individuals for whom this treatment would be most beneficial becomes an increasingly complicated issue.

Even within individuals with similar ASD symptomology, homogeneity was not observed for why safe street crossing behavior was problematic. While Steve and Colleen both presented as relatively high functioning individuals, their failure to execute safe behavior during street crossing appeared to differ. Steve presented as a child who simply did not know the behavioral expectations associated with safe street crossing (i.e., he failed to cross the street because he did not know what to do) as evidenced by the difficulty he experienced progressing through the rehearsal and modeling phases of BST. To complete these preliminary phases of the instructional package, he required three full sessions and 25 models. Additionally, during rehearsal Steve was observed to make comments such as, “I kind of forgot the steps.” In contrast, Colleen was able to progress through instructions and modeling in only one session consisting of ten models. She could confidently articulate the behavioral expectations associated with safe street
crossing, but seemed hindered by anxiety. Although no formal assessment of anxiety was conducted, behavioral observations support the hypothesis. While Colleen progressed through the initial versions of the rehearsal environment with little difficulty, her in-session demeanor changed markedly not when the level of difficulty increased, but when it was announced that the difficulty would change. The mere suggestion that an additional challenge would be presented, coupled with her desire to perform successfully, resulted in increased negative statements and outward signs of discomfort (e.g., she became more restless, held the joystick more tightly, and her hands trembled). As conceptualized by Skinner (1953, p.166), emotions such as the anxiety experienced by Colleen are induced by environmental conditions and accompanied by reflex responses, and they serve to alter the probability of a class of behaviors. As illustrated by the comparison of Steve and Colleen, the reason that skills are not executed may differ across participants, and therefore it may be advantageous to conduct a functional assessment of the unsafe behavior in an effort to tailor intervention strategies to better meet each child's needs.

While not inherently a limitation of the present study, an alternative conceptualization of safe street crossing may prove beneficial in future research. When assessing and treating safety skills deficits, it is important to remember that changes which appear notable via visual inspection of graphed performance may not be sufficient to result in clinical significance. In other words, if one error can produce egregious consequences, improvement from 0% to 75% accuracy may not be clinically significant. In the case of street crossing, the behavior can be subdivided into four primary steps. Doing this allows one to calculate the percentage of steps successfully executed. However, it is impossible to determine which step in the sequence may most directly
contribute to injury or death. In other words, one child may experience a person-to-car accident because he stepped into the roadway without looking to see if it was clear. Another child may experience a person-to-car collision if he does not use a crosswalk (i.e., oncoming traffic was not expecting to see an individual crossing at the location the child selected as a crossing zone). Given this uncertainty in determining the crucial role each step plays in keeping children safe, it may be more beneficial to evaluate each trial from a pass-fail perspective. Using this interpretive framework may more accurately address the issue of clinical significance. Future studies should consider this issue as data collection and analysis procedures are established.

Another important issue for future researchers to be mindful of is investigating which design features are critical for producing therapeutic effects and how those design features create their impact (i.e., understanding of the mechanisms for change). Although the existing literature offers some suggestions, additional research is necessary to establish guidelines for technology development and use with children with autism. The use of technology in interventions often requires technical or programming expertise that many clinicians lack making it necessary to foster multidisciplinary research and clinical work. It is imperative that behavioral clinicians and researchers partner with programmers and engineers to become more comfortable with these technologies and assist in developing or modifying tools to examine the questions that interest us.

Conclusion

Technology based interventions are often useful for and appealing to children with autism. A growing literature supports the general effectiveness of these tools although additional comparative research is needed. Interested researchers and clinicians
have a wonderful opportunity for exciting collaborations with other technical disciplines to make technology-based interventions truly useful and accessible for children with autism. The current study presents what is hoped to be preliminary data in a line of research whereby improvements in instructional technologies are made and clinically significant improvement in safety behavior is seen. While VR may ultimately prove to be a valuable enhancement to BST, and the theoretical underpinnings of this approach are sound, findings from the current study are not robust enough to indicate that the technology in its currently evaluated form should be considered best-practice for skill acquisition and generalization.
REFERENCES


Appendix A

Sample Recruitment Announcement
Sample Recruitment Announcement

Researchers in the psychology department at WMU are currently conducting a study designed to teach children with limited safety skills to behave more safely in street-crossing situations. Behavioral skills training, which uses a virtual reality training environment, will be used. If your child enjoys computers and/or video games, increasing your child’s street crossing skills is a priority for you right now, and you are willing to allow your child to participate in 1-2 hours of weekly session time for 1-2 months, you may be interested in this study. We are hoping to identify boys and girls between the ages of 9 and 15 who are diagnosed with Autism, Asperger’s, or PDD-NOS (or classified as Autistically Impaired through their school district). If you would like more information about this study, please call __________ to speak with a researcher.
Appendix B

Sample Newspaper Advertisement
Sample Newspaper Advertisement

VIRTUAL REALITY AUTISM STUDY – Researchers at WMU are studying the use of virtual reality to teach street crossing skills to children with Autism Spectrum Disorders (age 9-15). For more information, call ____________.
Appendix C

Recruitment Flyer
Western Michigan University

Are you interested in having your child participate in a safety skills research study using virtual reality?

Dear parent or guardian,

We are investigators at Western Michigan University who have an interest in studying the safety behavior of children with Autism Spectrum Disorders. We are currently conducting a study at the university which focuses on street-crossing safety, and your child may have an opportunity to participate. The study is designed to evaluate an intervention which uses virtual reality to teach children with limited safety skills to behave more safely in street-crossing situations. If increasing your child’s street-crossing skills is a priority for you right now, and you are willing to allow your child to participate in approximately 1 to 2 hours of weekly session time for 1 to 2 months, you may be interested in this study.

We are hoping to identify at least 6 children diagnosed with Autism, Asperger’s, or Pervasive Developmental Disorder Not Otherwise Specified (or classified as Autistically Impaired through his/her school district) who are between the ages of 9 and 15.

If you would like your child to participate in this study, please call ________ to speak with a researcher about your child’s eligibility to participate and to answer any questions that you may have. Please note that you have no obligation to let your child participate in this study.

Thank you,

Linda A. LeBlanc, Ph.D., Associate Professor, WMU
Tina R. Goldsmith, M.A., Doctoral Student, WMU
Telephone: ______________________ / E-mail: ______________________
Appendix D

Sample Script for Initial Contact with Parent/Guardian
Sample Script for Initial Contact with Parent/Guardian

This script represents the content of ongoing contact with parents/guardians after they have called to express interest in participating in the study.

a. Greeting, introduction and statement of status (professor or graduate student), and appreciation for interest
b. Describe the project
   1. Description of purpose
   2. Description of initial assessment that may result in exclusion from study
   3. Description of procedures
c. Determine further interest
d. Review of permission form and assent procedure with child
   1. Emphasize these points
      a) Invitation
      b) Risks, Benefits, Precautions, and Compensation
      c) Choice to withdraw at any time
      d) Who to call with questions
      e) Assent and session termination
e. If parents say they give permission, you can preliminarily arrange the first meeting (continue with f - g). If they say they would like to think about it, thank them for the interest and let them know they can contact us with any additional questions or to schedule a meeting with us if they decide to pursue participation (do not proceed with f – g until form is received).
f. Establish location, time, and date for meeting to review and sign permission forms and conduct initial screening if consent/assent are given.
g. Provide directions and parking instructions if necessary
Appendix E

Consent Document
Using Virtual Reality Enhanced Behavioral Skills Training to Teach Street Crossing Skills to Children and Adolescents with Autism Spectrum Disorders

WESTERN MICHIGAN UNIVERSITY
DEPARTMENT OF PSYCHOLOGY

Permission of Parent or Guardian

Principal Investigator: Linda A. LeBlanc, Ph.D.
Co-Investigator: Tina R. Goldsmith, M.A.

My child has been invited to participate in a research project entitled "Using Virtual Reality Enhanced Behavioral Skills Training to Teach Safe Street Crossing to Children and Adolescents with Autism Spectrum Disorders." This study will serve as a dissertation project for Tina Goldsmith, a doctoral student in the Clinical Psychology program of Western Michigan University, and all assessment and teaching sessions will be conducted in therapy rooms located in Wood Hall on the campus of WMU. (On-campus parking will be paid for by the researchers.) The purpose of this study is to conduct research to determine if our teaching techniques will improve children's street crossing behavior.

Although my child is being invited to participate because of his/her diagnosis, the researchers will do some initial testing of my child's current abilities to determine suitability for participation. This initial testing will include the administration of commonly used standardized tests (e.g., an intelligence test, ASD diagnostic testing) as well as direct observation of his/her safety skills. This initial testing should last no more than 4 hours paced appropriately for my child. Each testing session will last no more than 2 hours and will include play/rest breaks to reduce fatigue and any frustration that my child may experience. Initial testing will also involve observation of my child crossing the street in a staged context that he/she will think is real. Such testing may indicate that my child's current level of cognitive abilities and/or safety skills is either too low or too high to participate, and may therefore exclude my child from this study.

If test results indicate that my child is appropriate for this study, he/she will participate in videotaped sessions that will last no more than 1 hour, including play breaks. Depending on my child's progress and abilities, and scheduling, my child may participate in up to two visits per week. Scheduling of visits will depend on my child, family schedule, and staff availability, and it is estimated that, with regular attendance, my child will participate in 1-2 hours of research per week for 1-2 months.

The treatment phase of the study will consist of a virtual reality (VR) enhanced behavioral skills training (BST) package. The four primary components of BST involve (1) instructions, (2) modeling, (3) rehearsal, and (4) feedback. The instructions describe the skill and the models show someone doing the new skill. Next, my child will be given the opportunity to rehearse the skill using a computer generated virtual space like a computer game which will allow my child to practice the behavior in a safe environment.
Feedback means that right after crossing the street in the computer world, the program and the instructor will provide feedback such as praise or correction. My child can take a break at least every 15 minutes to rest or play in a nearby playroom, or play an age-appropriate computer game.

There may be some benefit to my child for participation in this study. His/Her safety skills may increase as a result of training. In addition, in the event the research is successful, the literature on safety skills training for children may be benefited.

Given the nature of this study, there are certain risks associated with assessing my child's safety behavior. In order to assess street-crossing safety, my child will be escorted to an on-campus, restricted traffic area. He/she will be instructed to cross the street to complete a task and then return, requiring my child to cross the street a second time. Although trained confederates will be present and in close proximity of my child at all times, there are certain risks associated with being in a natural street crossing environment (e.g., accidental physical injury). However, the researchers associated with the study will make every effort to reduce the likelihood of injury by controlling the environment to the greatest extent possible.

An additional, more minor risk associated with participation in this study is possible frustration that might occur when he/she does not successfully exhibit the desired safety behavior. To counteract this risk, sessions will include flexible break times and verbal praise will be used to reinforce my child's behavior. Additionally, sessions will be terminated if my child's verbal and/or physical noncompliance leads to a serious disruption of the session (e.g., kicking, screaming, throwing items, etc.). If two sessions in a row are terminated due to noncompliance, my child's participation will be reevaluated, and there will be a possibility that his/her participation in the study will end.

As in all research, there may be unforeseen risks to my child. However, these risks should be no different from those associated with the typical learning environment. If an accidental injury occurs, appropriate emergency measures will be taken. However, no compensation or treatment will be made available to me or my child except as otherwise specified in this consent form.

During the study, researchers will videotape the sessions with my child. These tapes are to be used only for the purposes of data collection and are to be kept confidential. All of the videotaped and written information collected in this study will remain confidential. That means that my child’s name will be omitted from all data collection forms and a code number will be attached. The principal investigator, Dr. Linda A. LeBlanc, will keep a separate master list with the names of the children and the corresponding code numbers in a locked cabinet in her research lab in Wood Hall at WMU. Information collected in this study may be presented in professional journals and at conferences to assist other clinicians, educators, and researchers in their understanding of children and adolescents with Autism Spectrum Disorders. Any presented information will be anonymous and my child’s name will not be used. All written information (e.g., data sheets, consent forms, etc.) and videotapes will be stored for at least 3 years in locked file cabinets in the Autism and Developmental Disabilities Laboratory (Wood Hall – 1534) at WMU. Subject numbers instead of names will be used to identify all stored data and videotapes. The only computer files will be graphing files and no identifying information will be included.
At the conclusion of the study I will have the opportunity to meet with the researcher to discuss my child’s performance during the study. Additionally, at the conclusion of the study, I will be provided with a one-page questionnaire that asks for my opinions regarding the study. I will be asked to complete the form and mail it back to the researchers in the provided self-addressed, pre-stamped envelope. I will not be asked to include my name or any other identifying information on the questionnaire. In other words, my results will be anonymous.

At any time I may withdraw my child from this study. Withdrawal from this study will not affect my family’s affiliation with the agency/school through which I was contacted or Western Michigan University. If I have any questions or concerns about this study, I may contact Dr. Linda A. LeBlanc (269-387-4920) or Tina R. Goldsmith (269-387-4363). I may also contact the Human Subjects Institutional Review Board (269-387-8293) or the Vice President for Research (269-387-8298) if questions or problems arise during the course of the study. This permission document has been approved for use for one year by the Human Subjects Institutional Review Board as indicated by the stamped date and signature of the board chair in the upper right corner of both pages. I cannot participate in this project if the stamped date is older than one year.

My signature below indicates that I, as parent or guardian, can and do give my permission for ______________________ (child’s name) to participate in the previously described experimental intervention, and also indicates that I can and do give my permission for personal involvement as outlined above (i.e., completion of questionnaire at the end of the study).

___________________________________________  _______________________
Parent’s Printed Name                                 Phone Number

___________________________________________  _______________________
Parent Signature                                    Date
Appendix F

Assent Document
Using Virtual Reality Enhanced Behavioral Skills Training to Teach Safety Skills

Western Michigan University
Department of Psychology

Child Assent

Principal Investigator: Linda A. LeBlanc, Ph.D.
Co-Investigator: Tina R. Goldsmith, M.A.

______________________________
(Child’s Name)

We would like to work with you for the next several weeks. During our time together, we are going to teach you a safety skill using a computer program. First, we will talk about the skill and then you can practice using the computer.

Would you like us to teach you a safety skill?

☐ Yes
☐ No

______________________________
Child’s Signature

______________________________
Assent Obtained By

______________________________
Date

______________________________
Date
Appendix G

Demographic and Background Information Form
Demographic and Background Information

Participant ID Number: _____  Date Form Completed: _____

Child's Age: ______  Child's Gender: Male / Female

Child's Diagnosis: ____________________________________________

Other disabilities or special needs: ________________________________

__________________________________________________________________

Child's current educational placement: (regular ed, special ed, etc.)

__________________________________________________________________

__________________________________________________________________

Has your child previously received safety skills training/education for street crossing? Yes / No

If yes, please describe the nature of the training/education and whether it was, in your opinion, successful:

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

Please describe your child's level of experience with multimedia equipment, including the use of video games, joysticks, television, computers, etc.

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________
Appendix H

Script for Informing Parents of Results from Initial Screening
Sample Script for Informing Parents of Results from Initial Screening

This script represents the content of ongoing contact with parents/guardians after initial screening. The tone of this contact will be positive and supportive despite the outcome of the initial screen.

a. Greeting and, if necessary, introduction and statement of status (professor or graduate student)
b. Introduce purpose of call/visit- to inform them of the results from the initial screening
c. Review test results in laymen’s terms
   a. Note child’s strengths
   b. Note areas for improvement
   c. Indicate whether child’s current level of ability makes him/her suitable for inclusion in study
      1. If yes...
         a) Indicate why he/she may benefit from the study
         b) Answer any questions that parent/guardian may have
         c) Determine further interest
         d) Schedule next visit
      2. If no...
         a) Indicate why the child’s abilities make him/her not suitable
            a. Already possesses the skill targeted in this study
            b. Cognitive ability too low
            c. Sensory or other conditions that do not allow participation in study as it is designed (e.g., visual impairment)
            d. High level of noncompliance (as determined by observation during initial screening)
         b) Encourage parent/guardian to continue working on safety skills and, if they an interest in pursuing other professional means of skill training, refer them to the WMU Psychology Clinic (387-8302) for treatment services. Also, remind him/her that the results in no way indicate that their child is not capable of learning safety skills; exclusion was simply necessary due to the fact that the study needs a group of kids who have a very specific set of skills and abilities.
         c) Thank them for their time
Appendix I

Photos of Primary Street Crossing Area
Photos of Primary In Situ Street Crossing Area:
WMU Campus – Fetzer Center Area
Appendix J

Street Crossing Data Sheet
# Street Crossing Data Sheet

<table>
<thead>
<tr>
<th>Trial</th>
<th>Stop &amp; Wait on Sidewalk</th>
<th>Look L &amp; R Until Clear</th>
<th>Walk &amp; Continue Looking</th>
<th>Use Crosswalk</th>
<th>What Happened</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Y / N</td>
<td>Y / N</td>
<td>Y / N</td>
<td>Y / N</td>
<td>M / A / C</td>
</tr>
<tr>
<td>P / R</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Notes:</td>
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<tr>
<td></td>
<td>Y / N</td>
<td>Y / N</td>
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<td>P / R</td>
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<td>Notes:</td>
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</tr>
</tbody>
</table>

**Stop and Wait on Sidewalk**: For real-world trials, score Y if child stops and waits at least 4 inches away from the edge of the sidewalk with body oriented towards the street. For VR trials, score Y if child stops on the street-side of the sidewalk with body oriented towards the street.

**Look Left & Right Until Clear**: Score Y if, while stopped, the child looks left and right in the direction of potentially oncoming traffic and continues to do so until all traffic has passed.

**Walk & Continue Looking**: Score Y if child walks in a continuous forward manner while looking left and right (in the direction of potentially oncoming traffic) at least 1 time per lane. Skipping, hopping, etc. should result in a N.

**Use Crosswalk**: Score Y if, while crossing, child remains within the designated crosswalk at all times. If trial is aborted by the therapist, or if trial ends because of child-car collision, score Y if child was within boundaries of crosswalk from beginning of crossing until the time the trial was terminated.

**Notes**: Use the "notes" section to record any unusual behavior (e.g., swerving in and out of crosswalk) or problematic behavior (e.g., pushing other pedestrians, yelling, etc.)

**P / R**: P = Primary Data Collector, R = Reliability Data Collector

**M / A / C**: M = Made it across (i.e., child maneuvered him/herself from one side of the street to the opposing side); A = Aborted (i.e., therapist ends trial before child has maneuvered him/herself to the other side of the street); or (b) C = collision (i.e., child collides with a moving vehicle).
Appendix K

BST Procedural Integrity Data Sheet
<table>
<thead>
<tr>
<th>Action</th>
<th>Y / N</th>
<th>Score Y/N in excel sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provided rationale</td>
<td>Y / N</td>
<td></td>
</tr>
<tr>
<td>Quizzed rationale</td>
<td>Y / N</td>
<td></td>
</tr>
<tr>
<td>Described steps</td>
<td>Y / N</td>
<td></td>
</tr>
<tr>
<td>Quizzed steps</td>
<td>Y / N</td>
<td></td>
</tr>
<tr>
<td>Probed to make sure all Qs were answered</td>
<td>Y / N</td>
<td></td>
</tr>
<tr>
<td>Provided at least 4, clear models</td>
<td>Y / N</td>
<td></td>
</tr>
<tr>
<td>At least 2 models were &quot;what not to do&quot;</td>
<td>Y / N</td>
<td></td>
</tr>
<tr>
<td>Discussed each model and answered Qs</td>
<td>Y / N</td>
<td></td>
</tr>
<tr>
<td>Correct version of trial presented</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provided praise and/or corrective feedback</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix L

Sample Map Provided to Driver
Route 1

- Follow red arrows until they turn into blue. Then follow blue arrows to loop around and return to your starting point.
- Once you reach your starting point, drive your assigned route again.
- Remember: Drive the designated speed limit- 20 MPH.
Appendix M

Instructions for In Situ Data Collection
Instructions for In Situ Data Collection

1. Take your data sheet, a book, and a pen and walk to your designated crosswalk. You can sit on a bench, pretend to do your homework or casually stand around. Remember that the participant is not supposed to know that you are there to take data.

2. Wait there until you see the child walking down the sidewalk. When the child and the primary researcher get to the crosswalk the researcher will stop and ask the child to cross alone.

3. As the child is walking, please make sure you are watching for the four components of safe street crossing that are listed on your data sheet (use the crosswalk, wait at the curb, look left and right, walk and continue looking).

4. Quickly and inconspicuously fill out your data sheet and prepare to watch and collect data on the participant walking back across the street.

5. At the end of the session return to the designated meeting location.
Appendix N

Instructions for Pedestrian Safety Monitors
**Instructions for Pedestrian Safety Monitor #1**

1. Wait at your designated crosswalk until you see the participant and the researcher walking down the sidewalk. The child cannot know you are there to watch them so you need to act casual (pretend to talk on your cell phone, etc.)

2. When the child and primary researcher get to the sidewalk the researcher will ask the child to cross the street on their own.

3. Once the participant begins to cross the street, you casually walk one arm’s distance behind and slightly to the side of the participant. **It is your responsibility to ensure his/her safety! Please be cautious. If at any point the participant’s safety is compromised the trial will be terminated, you should break character and the unsafe situation should be remedied.**

4. After the child has crossed safely you need to proceed to your next designated area and continue to act casual.

5. At the end of the session, return to the designated meeting location.

**Instructions for Pedestrian Safety Monitor #2**

1. Wait at your designated crosswalk until you see the participant and the researcher walking down the sidewalk. The child cannot know you are there to watch them so you need to act casual (talking on your cell phone, etc.)

2. When the child and primary researcher get to the sidewalk the researcher will ask the child to cross the street on their own. Safety pedestrian number 1 will walk behind him/her as he/she crosses. Make sure you are ready to cross the street behind him/her.

3. Once the participant begins to walk back across the street, you casually walk one arm’s distance behind and slightly to the side of the participant. **It is your responsibility to ensure his/her safety! Please be cautious. If at any point the participant’s safety is compromised the trial will be terminated, you should break character and the unsafe situation should be remedied.**

4. After the child has crossed safely you need to proceed to your next designated area and continue to act casual.

5. At the end of the session, return to the designated meeting location.
Appendix O

Instructions for Drivers
Driver Instructions

Your purpose during in-vivo data collection is to assist in creating traffic flow in a designated area of WMU's campus. With confederates, such as yourself, driving vehicles, it allows us to have greater control over environmental variables, thereby creating a safer data collection environment for our participants.

The instructions provided below must be followed as closely as possible to ensure the safety of everyone involved in the session. Since motor vehicles will be involved in our naturalistic data collection environment, there is a potential for serious injury if instructions are not followed correctly.

1. **Be on the look-out for the participant.** Before the session you will be provided with visual descriptive information about the participant (e.g., what they are wearing, skin tone, height, etc.). This information will make the participant more readily identifiable, and therefore increase your ability to safely navigate your vehicle when you are in close proximity to the child. Remember, any information that could lead to identification of participants must remain confidential.

2. You will be provided with a printed map detailing your route. If anything is unclear, please ask. To ensure your safety, and the safety of our participant, it is important that you **do not refer to the map while driving**.

3. **Follow your route and do not stop unless necessary** (e.g., stop signs, unsafe driving situation, etc.). If at anytime you deviate from your route, do your best to return to your route as soon as possible.

4. You are **not allowed to have a passenger** with you.

5. Both front seat **windows must be down** and your **radio must be turned off** while driving. You need to be alert and able to hear environmental cues, including verbal instructions from the researchers if an unsafe situation were to arise.

6. You **must be very alert** every time you are approaching the cross walks. It is possible that the participant will cross in an unsafe manner. **If the child's in danger, honk your horn, slow down, and come to a complete stop if necessary.** If the situation becomes unsafe, the researchers may end the session early. If this occurs, go directly to the designated meeting location.

7. You must **wear your seatbelt** while driving.

8. You must **obey the speed limit**. This information is noted on your map.

9. You must **have a cell phone with you** so we can contact you in case of emergency. However, you should not use your phone for any other reason.

10. Sessions should last approximately 15 minutes. **If you drive through the crossing zone near crosswalks 3, 4, 5, and 6 and do not see a research assistant sitting on the large rock in the center island, you should park and return to Wood Hall 1509.**

    
    **** If you need to contact the researcher, call ____________ ****
Appendix P

Joystick Training Environment 1
Appendix Q

Joystick Training Environment 2
Appendix R

Therapist Job Aid
Therapist Job Aid: BST for Street Crossing

Street Crossing Safety

1. Use the crosswalk.
2. Wait at the curb.
3. Look left and right for cars. (clear?)

Instructions

• Provide rationale and basic information:

Whenever you cross a street, it’s very important to stay safe. No matter how small or large a road is, oncoming traffic can be quite dangerous. So, you must always use safe street-crossing skills to avoid danger to yourself and others.

• Informally quiz to make sure that he/she understands the rationale:

When should you use safe street crossing skills? – Always
What if it’s a little street that hardly ever has cars or trucks on it, do you still have to use your safe street crossing skills? – Yes
Why is it important to use safe street-crossing skills? – To avoid danger/harm to myself and others

Provide additional information as necessary. Answer all relevant questions, and when it’s clear that the child understands the rationale, proceed to the next training step. DON’T FORGET TO PRAISE FOR PARTICIPATION AND CORRECT RESPONDING!

• Review steps:

1. If you want to cross the street, it’s important that you use a crosswalk whenever one is present. Not all streets have crosswalks, but if one is available, you should use it. Crosswalks can be different from street to street. So, here are a few examples of crosswalks that you might see. (Show pictures of various crosswalks and point out differences.) Also, look for crosswalk signs. They also vary. So, here are a few examples. (Show pictures of crosswalk signs and point out differences.) If you see a crosswalk sign, a crosswalk is probably pretty close by. Stay inside the crosswalk the while time.
2. Once you walk to the crosswalk, it's important that you wait at the curb for traffic to clear. It's best to stand at least a foot away from the curb while you wait to cross.

3. Once you're positioned at the curb next to the crosswalk, it's time to check to see if it's clear. For this step, you should look left and right for oncoming traffic. In order to cross, traffic coming from both sides must be clear—in other words, there shouldn't be any cars coming, unless they are very, very far away. If there are cars coming, and they seem far away, but you're not sure, just wait. There's no need to rush.

4. Once clear, you should cross. This involves quickly walking—not running, skipping, hopping, etc. – across the street. As you walk it is very, very important that you continue turning your head to the right and left so that you can make sure new cars and trucks aren't coming your way. Look 1x per lane.

So, again, the steps are (1) Use the crosswalk, (2) Wait at the curb, (3) Look left and right for cars, and if clear (4) Walk while continuing to look.

- Informally quiz to make sure that he/she understands the steps:

  Now, you tell me what the 4 steps are.

  Continue to review the steps as necessary until the child can state the 4 steps. If the child is struggling, you may introduce the skill card as an additional instructional aid. DON'T FORGET TO PRAISE FOR PARTICIPATION AND CORRECT RESPONDING!

- Probe to make sure that there are no unanswered questions.

  Do you have any other questions about safe street crossing?

  Do you have any questions about pedestrian safety in general?

  Answer all relevant questions and, if session time has not expired, proceed to the next BST step.

**Modeling**

Therapist and/or research assistants should model the desired safety behavior. At least 4 models should be provided. Each one should be paced such that the individual steps are clear and exaggerated to promote attending. At least 2 of the models should include a poor execution of the safety skill. Following each model, discuss what just transpired and answer any questions that he/she may have.

**Rehearsal & Feedback**

Use VR program for rehearsal.

Complete a trial, and then provide descriptive praise and corrective feedback.

Provide periodic breaks.
Appendix S

Visual Aids Used During Instructional Phase
Pedestrian Crossing Signs and Signals
Pedestrian Crosswalks
Skill Card

Street Crossing Safety

1. Use the crosswalk.
2. Wait at the curb.
3. Look left and right for cars. (clear?)
Appendix T

Rehearsal Environments 1 and 2
Appendix U

Rehearsal Environments 3 and 4
Appendix V

HSIRB Approval Letter
Date: April 25, 2006

To: Linda LeBlanc, Principal Investigator
    Tina Goldsmith, Student Investigator for dissertation

From: Mary Lagerwey, Ph.D., Chair

Re: HSIRB Project Number 06-02-06

This letter will confirm that your research project entitled "Using Virtual Reality Enhanced Behavioral Skills Training to Teach Street Crossing Skills to Children and Adolescents with Autism Spectrum Disorders" has been approved under the full category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may only conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: February 15, 2007