

Case Study: Using a Virtual Reality Computer Game to Teach Fire Safety Skills to Children Diagnosed with Fetal Alcohol Syndrome

Lynne S. Padgett,^{1,2} PhD, Dorothy Strickland,² PhD, and Claire D. Coles,¹ PhD

¹Marcus Institute, a Division of Kennedy-Krieger Institute at Emory University and ²Do2Learn.org, Virtual Reality Aids, Inc.

Objective To assess the effectiveness of a computer-based virtual reality (VR) game in teaching five children diagnosed with fetal alcohol syndrome (FAS) fire safety skills and to generalize these skills to a real world simulation. **Method** Children participated in a study by using a multiple baseline, multiple probe design. Before the game, no child could correctly describe what actions to take during a home fire. A computerized game allowed them to learn the recommended safety steps in a virtual world. Skill learning and real-world generalization were tested immediately after the intervention and at 1-week post-test. **Results** All children reached 100% accuracy on the computer intervention, defined as successfully completing each of the safety steps. At the 1-week follow-up, all the children were able to perform the steps correctly in a real world simulation. **Conclusions** The results suggest that this method of intervention warrants further study as an educational delivery system for children with FAS.

Key words fetal alcohol syndrome; fire safety; injury prevention; intervention.

Fetal alcohol syndrome and partial fetal alcohol syndrome (FAS/pFAS) result from prenatal exposure to alcohol (Stratton, Howe, & Battaglia, 1996). It is estimated that 1 in 30 pregnant women consume alcohol at levels (i.e., five or more drinks per occasion or seven or more drinks per week) that can place their offspring at risk for some of the negative consequences of prenatal alcohol exposure (Centers for Disease Prevention and Control, 2003a). Current Centers for Disease Control and Prevention studies have documented approximately 1300–8000 children with FAS/pFAS are born each year (Centers for Disease Prevention and Control, 2003b).

Effects of prenatal exposure can include craniofacial abnormalities, growth deficiencies, and central nervous system dysfunction, including mental retardation and behavioral problems with deficits persisting throughout life (Streissguth, 1994). Although profiles vary among individuals diagnosed with FAS/pFAS, commonly reported traits among clinically referred preschool children include (a) problems in learning and preacademic

skills, (b) arousal dysregulation (impulsivity and hyperactivity), (c) poor adaptive skills, (d) unresponsiveness to verbal danger cautions, (e) difficulty in generalization from one learning setting to another, and (f) behavior and discipline problems. It is anecdotally reported that children with FAS are “unteachable” (Sanders, 2001). Problems are reported even in children who have average cognitive abilities. In research samples, specific learning problems observed include difficulties with motor and fine motor development, and visual–spatial relationships. These characteristics place children with FAS/pFAS at particularly high risk for unintentional injuries and could make it difficult to teach them safety skills.

Unintentional traumatic injury is the leading preventable health problem for children and fire in the home is a significant threat to young children. Among children aged 1–9 years, fires and burns are the third leading cause of unintentional injuries behind motor vehicle/traffic accidents and drowning. Children with

All correspondence concerning this article should be addressed to Lynne S. Padgett, Marcus Institute, A Division of Kennedy-Krieger of Emory University, 1920 Briarcliff Road, Atlanta, Georgia 30329.
E-mail: lymepadgett@yahoo.com, lpadget@emory.edu

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limitations in cognitive, social, and emotional functioning are more than twice as likely to die in a fire (Injury Prevention for Children with Special Health Care Needs Work Group, 1999).

In response to these dangers, safety protocols for children have been developed. Safety agencies such as the United States Fire Administration (USFA) note that individuals with disabilities are at greater risk of harm (United States Fire Administration, 2002a) and can benefit from increased practice and specialized safety training programs. For the prevention of fire injuries, families are encouraged to develop a home evacuation plan. Teaching children the steps in this evacuation plan is an integral component of fire prevention. Children with cognitive limitations require modifications in learning methods and those who are unable to generalize easily from one situation to another require repeated practice.

There is little research on learning interventions for children with FAS/pFAS; however, Morse and Weiner (1993) suggest that elementary-aged children with FAS/pFAS benefit from specialized curriculums. Research in other populations indicates that learning is enhanced in brain-damaged individuals when information is presented in multiple modalities allowing individual to access different areas of memory when recalling the information (Parente & Herrman, 1996; Sohlber & Mateer, 2001). Virtual reality (VR) computerized games allow multiple sensory inputs to be presented in a format that is interesting to children and allow them to learn at their own rate. Children find games salient, enjoyable, and are able to operate them with little or no parental assistance so that repeated practice is more feasible. The VR modality, which allows the illusion of presence in a computer-generated environment, combined with explicit real world generalization techniques reinforces safety skills by using visual and verbal cues, spatial skills, and physical action in the learning process. This illusion can be created through by using complex equipment such as a headset and body tracker, or more standard input as simple as a personal computer and monitor with a joystick, keyboard keys, or a mouse. With standard input design, the computer scenes are changed to give the illusion of interaction with the imaginary world.

Our goal was to develop and evaluate an effective game that can be played independently by a child with FAS/pFAS, without direct assistance from a parent or observer. Therefore, the game needed to be engaging and self-explanatory, providing directions and needed corrections to the child. Past research has demonstrated that a VR computer game can be used effectively to teach important safety skills to individuals with both mental and physical disorders (Foreman, Wilson, & Stanton, 1997). An earlier version of this VR game was used to teach safety skills to autistic children (Strickland, Marcus, Mesibov, & Hogan, 1996). The aim of the current case series was to evaluate the efficacy of this computerized intervention for individuals with FAS/pFAS. We hypothesized that the VR game would lead to increased knowledge of fire safety skills that could be generalized to a real world simulation.

Methods

Participants

Participants were recruited from the Fetal Alcohol Clinic at Marcus Institute, a Division of the Kennedy-Krieger Institute at Emory University. Criteria for study eligibility were the child had to be aged 4–7 years, diagnosed with FAS or pFAS, and in a permanent custody arrangement. Like many children with FAS, five participants were adopted and had been with their adoptive family a minimum of 2 years. Participants had ability scores in the mild mental retardation range ($IQ > 50$) or above based on cognitive testing available in medical records. Table I summarizes the participant characteristics. All caregivers completed an informed consent procedure approved by the Emory University School of Medicine's Internal Review Board. Table I provides demographic data for each participant. Estimated intellectual functioning was obtained from the child's most recent cognitive evaluation.

Measures

The home fire safety program used is based on USFA (2002a) guidelines for young children. The three steps involve (a) recognizing a fire danger in the home,

Table I. Participant Characteristics

Child ID	Age	Gender	Ethnicity	Diagnosis	Estimated intellectual functioning (score range) ^a
1	5 years, 2 months	Female	European American	Partial fetal alcohol syndrome	Average (90–110)
2	6 years, 2 months	Male	African American	Fetal alcohol syndrome	Low average (80–89)
3	6 years, 3 months	Male	European American	Fetal alcohol syndrome	Borderline (70–79)
4	7 years, 3 months	Male	European American	Fetal alcohol syndrome	Low average (80–89)
5	5 years, 10 months	Male	European American	Partial fetal alcohol syndrome	Deficient (mild) (55–69)

^aIQ score range ($M = 100$, $SD = 15$).

(b) leaving the home immediately by the shortest safe route, and (c) waiting at a preassigned meeting place outside the home. The intervention used a VR game based on these guidelines. A preliminary step involved programs to require the child to correctly identify each object (fire, meeting place) or action (follow, sit, wait) necessary to play the game from among a random array by clicking on the correct picture. Each child was trained to a criterion of 100% accuracy before beginning the VR game.

Because an earlier version of this game was used with autistic children (Strickland et al., 1996), modifications to the format were required to make it more engaging to children with FAS. The VR world was modified to include more verbal instructions, background music, and to provide more visual cues within the house (e.g., adding more color, placing pictures on the wall) to accommodate the typical verbal strengths and visual-spatial and fine motor weaknesses of children with FAS. Accommodations to facilitate navigation through the house made this game easier to navigate than most commercially available 3D games.

Procedures

The efficacy of the VR format as an instructional tool was evaluated by using a multiple baseline, multiple probe, pre–post case series design. This design is a frequently used learning technique for children with disabilities (Horner & Baer, 1978). In addition, given the lack of research evaluating educational interventions with alcohol-affected children, a pre/post-learning case series model was an appropriate design to determine if further studies are warranted (Gelso, 1979).

Each child was seen for two visits: an initial visit consisting of pretesting and training and a post-test visit. During a prelearning phase, each child was asked to arrange in correct order a set of three pictures that represented the USFA home fire safety steps. To assure that these steps were unfamiliar, researchers asked each child verbally what he or she would do if they saw a fire. Answers given by the children were “put it out,” “call the fire department,” or “I don’t know.” No child indicated prior knowledge of proper steps, either through picture sequencing or demonstrating correct actions. After this pretest, each child was trained to 100% accuracy on the fire safety components before beginning the intervention in the virtual world.

A second precursor was learning how to navigate in the virtual world. To prevent the children’s compromised visual-spatial abilities from interfering with learning, researchers designed an initial module, the treasure

hunt, to teach navigation in the VR world. All children learned to navigate successfully the virtual world with either the directional keys or joystick after two series of treasure hunts. Next, each child completed the required tasks to learn three fire safety steps in the virtual world. This training sequence consisted of two conditions (no fire present, fire present in several places), each with three levels. The three levels in each condition were (a) animated guide led, yellow arrows indicated the correct path out of the house; (b) animated guide led, no arrows; and (c) no guide, no arrows. This design provided extensive navigational support at early levels to shape the child’s responses in the VR house. As the level of support was reduced, the children successfully practiced the steps without program cues. The game tracks the child’s motion, and the character responds to correct actions with positive reinforcements such as jumping and saying “Good job.” If the child attempts a dangerous motion, such as walking into a fire, the screen goes black, the danger is explained, and the child is placed back at the game’s beginning. This procedure prevents the child from being reinforced by the game for dangerous behavior.

All instructions were administered by computer, either with auditory commands or by having the animated character demonstrate. The observing experimenter gave no directions or assistance, verbally or otherwise, during training. This protocol is consistent with our goal of developing a self-contained game that can be provided through a Web-based format that is accessible by children and parents for repeated play.

After demonstrating competence in the virtual training environment, the child was asked to generalize their knowledge. First, the child was asked to arrange the original set of three pictures, and second, to respond to an imaginary fire in the building. The examiner recorded the child’s responses. At the end of the session, parents were instructed not to review the steps with their children during the following week, although they could discuss the experimental session if the child initiated the discussion.

Approximately 1 week later, the child returned for a follow-up visit. During this visit the child’s retention of the three safety steps was assessed by using the same picture arrangement procedure and imaginary real-world scenario.

Results

In the two pretests (verbal inquiry and picture arrangement), no child demonstrated knowledge of correct

home fire safety procedures. All children were successfully taught to recognize components used in the VR game, after no more than four practices with the support programs (recognition games and treasure hunt).

After training with the VR game, all children were able to successfully complete each of the three safety steps in the virtual world. Immediately after computer training, four of the children demonstrated generalized knowledge by correctly sequencing pictures. All of the children ($n = 5$) were able to place the picture illustrating step 1 correctly. Four of the children were able to correctly place the picture illustrating step 2. One child (case 5) refused to use the picture illustrating the second step. All of the children were able to correctly place the picture illustrating step 3.

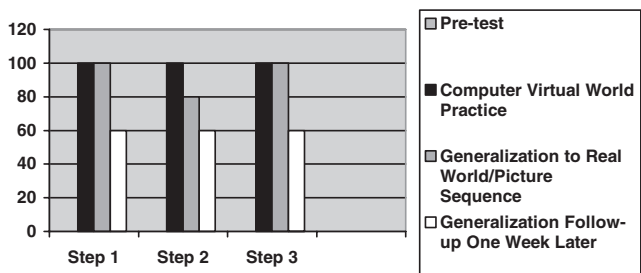
Immediately after training, four of the children (cases 1–4) were able to generalize steps 1 and 2 (recognize fire, leave home) correctly in response to an imaginary building fire and all of the children ($n = 5$) were able to generalize step 3 (sit and wait at the meeting

place) correctly in response to an imaginary building fire. The child who did not receive credit for generalizing steps 1 and 2 did not articulate them, but rather ran from the building and went to the correct meeting place saying “sit and wait, sit and wait” (step 3). He was unable to articulate or describe steps 1 and 2.

The level of accuracy for the picture arrangement task was lower at the 1-week follow-up, with 3 of the children (cases 1, 2, and 4) arranging all three pictures correctly and two of the children (cases 3 and 5) unable or unwilling to do so. However, all five of the children were able to generalize steps 1 through 3 to the real world simulation of an imaginary fire.

Final results indicated all five children correctly identified fire safety components 100% of the time and four correctly performed all three safety steps in both real world simulation and picture sequence test with 100% accuracy after training. All results are presented in the Figures 1 and 2.

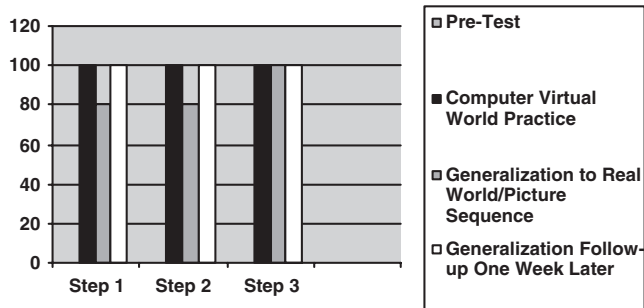
Picture Sequence Generalization
Percentage Accuracy at Each Step



Step 1- Recognizing Fire Danger
Step 2- Go outside by the shortest safe route
Step 3- Wait at a designated meeting place

Figure 1. Picture sequence generalization percentage accuracy at each step. Step 1, “recognizing fire danger”; step 2, “go outside by the shortest safe route”; and step 3, “wait at a designated meeting place.”

Real World Generalization
Percentage Accuracy at Each Step



Step 1- Recognizing Fire Danger
Step 2- Go outside by the shortest safe route
Step 3- Wait at a designated meeting place

Figure 2. Real world generalization percentage accuracy at each step. Step 1, “recognizing fire danger”; step 2, “go outside by the shortest safe route”; and step 3, “wait at a designated meeting place.”

Discussion

Alcohol-affected children often have cognitive impairments that place them at elevated risk for injury. This study sought to evaluate the efficacy of a computer-based intervention to teach home fire safety skills and the generalization of those skills to an imaginary fire. The aims of the study were achieved on several levels. Each child was able to use the computer-based VR intervention and generalize these same steps to the real world. There was less success generalizing the safety steps to a picture sequence. The discrepancy between demonstrating the correct actions and being able to sequence those actions in pictures in follow-up testing may have resulted from the children finding the computer training and real world physical reinforcement of the learned activities more salient for learning retention. It is also notable that the two children unable to correctly sequence the pictures also had the lowest intellectual functioning. In addition, the children played the game independently supporting the goals of distributing the game in a self-contained, Web-based format.

The children were very enthusiastic during the study, even in follow-up testing where the computer was not used. Several children requested pictures of the animated character, who originally provided directions in the virtual world. Anecdotally, upon seeing four of the five children (cases 1–4) at the clinic for other appointments during the following months, the children remembered all or part of the training and spontaneously recited it to the observer. In general learning, success may be due largely to the establishment of a baseline of knowledge to effectively play the game (learning objects, actions, navigating in the virtual space), high engagement level with the game format, the generalization of the learning to the real world, and use of multiple modalities (visual, spatial, auditory, and physical activity).

Despite the apparent effectiveness of the game, several cautions are urged when reviewing the results. First, this is a case series design with a small sample size. In addition, the brief (1-week) follow-up period limits also the strength of the findings, as well as their generalizability to longer follow-up periods. Though these constraints are appropriate to the aims of this study, further research is needed to validate the results, including comparison with the performance of children with other disabilities and typical controls over longer periods. In addition, this program did not attempt to teach a full range of fire safety skills, which usually include actions you are NOT supposed to practice, such as “don’t pick up toys” as you exit. USFA and many fire safety programs (Jones,

Kadzin, & Haney, 1981) include other features such as instruction on testing doors for heat before opening. Finally, testing real world generalization suffered from the inability to test how a child would react in a real fire. For obvious reasons, no child was placed in a situation with a real fire to determine generalizability. However, the USFA recommends that all children be taught and practice fire escape plans in their home every month (United States Fire Administration, 2002b). The virtual program allows children with FAS/pFAS, who have specific cognitive deficits resulting from prenatal alcohol exposure to do this in a safe, engaging way.

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