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Research Article

Effectiveness of Virtual Reality Technology in Teaching Pedestrian Skills to Children with Intellectual Disabilities[1]

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Abstract

Pedestrian skills are important for children with intellectual disabilities to continue their daily lives independently. This study aims to determine the effectiveness of virtual reality in the acquisition and maintenance of pedestrian skills for children with intellectual disabilities. In addition, the effect of virtual reality on participants generalizing their pedestrian skills to real environments has also been examined. In the study, social validity data were collected from the participants and their mothers regarding the results of the study. Three intellectually disabled children between the ages of 11 and 15 participated in the study. In the study, a multiple probe design with an inter-participant probe trial, which is one of the single-subject research models, was used. It is seen that all participants learned pedestrian skills and continued the skills they learned one, three, and five weeks after the completion of the instruction. In addition, all participants were able to generalize their skills to the real environment (pedestrian crossing and illuminated pedestrian crossing). When the social validity data collected from the participants and their mothers were examined, it was revealed that teaching with virtual reality applications is interesting and fun, in addition, it can be used for different educational purposes.

Keywords: Pedestrian skills, using the crosswalk, using the illuminated crosswalk, virtual reality, children with intellectual disabilities.

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[1] This article is derived from Veli Emre KURTÇA's PhD thesis, prepared under the supervision of Assoc. Prof. Dr. Deniz Mertkan GEZGİN. This study was presented as an oral presentation in VI. International Applied Social Sciences (2022).

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Introduction

Since ancient times, individuals with mental disabilities have been exposed to different practices and labels according to the needs of the society they live in, due to their characteristics or the difficulties they experience in daily life (Bryan, 1974). In the historical process, the definition of intellectual disability and the dynamics that make up the definition have changed in order to prevent the labeling of individuals with intellectual disabilities. In the 12th guideline published by the *American Association on Intellectual and Developmental Disabilities* (AAIDD) in 2010, the support services provided to the individual were highlighted and it was emphasized that the level of functioning of the individual would increase provided that adequate and appropriate support services are not permanent. The definition included the criterion of *'significant limitations in cognitive functions, limitations in adaptive skills, and the occurrence of this condition before the age of 18'*.

In the last guideline published by AAIDD in 2021, the definition was updated as *“significant limitations in cognitive functioning and adaptive skills that also affect conceptual, social and practical adaptation skills, and these limitations appear before the age of 22”.* For adaptive behavior, in the 2021 guideline, the expression *'The sum of the conceptual, social, and practical skills learned and used by people in their daily lives'* is included. The definition and the change in the dynamics that make up the definition aim to provide appropriate support and training services, by preventing labeling (AAIDD, 2010).

The purpose of support and education services is to enable individuals with intellectual disabilities to function independently in their daily life, school, and work environments. Intellectually disabled individuals need frequent repetition, hints, or intensive training to learn many skills that their peers randomly learn in their daily life or school life (Friend, 2006). This situation makes the usage of scientifically based applications compulsory, which are effective and will provide the most benefit to the individual (Browder et al., 2020). A systematic evaluation process is required to determine the academic, self-care, language-communication, safety, and daily life skills needs of individuals with intellectual disabilities and to provide support services. The evaluation process is important for determining the skills needed by the individual and for the preparation of training programs for the individual (Wehmeyer et al., 2016; Turnbull et al., 2020). Individualized Education Programs (IEP), which will be prepared by taking into account the strengths of mentally handicapped individuals, will enable them to lead their lives independently. Teaching safety skills has vital importance in order to prevent risky situations and events that may be encountered during and after the transition to an independent life, and to protect the mentally retarded individual (Mechling, 2008).

Security skills are the skills that an individual needs to avoid possible harm, protect himself from the harm that occurs in sudden situations, or end the situation when faced with verbal or non-verbal negative behaviors and situations such as accidents, fire, kidnapping, and harassment (Clees & Gast, 1994; Jang, Mehta & Dixon, 2016). Difficulties in inference, reasoning, vision, communication, and motor skills or psychopathological situations cause intellectually disabled children not to realize that they may be harmed when they are exposed to dangerous situations and not be able to protect themselves from these situations. Such situations can result in intellectually disabled children being exposed to harassment, violence, or life-threatening situations in everyday environments such as home, school, or public places (Zirpoli, 1986; Gast et al.,1992; Levy and Packman, 2004). While individuals with normal development acquire these skills randomly along with maturation, cognitive development, and the situations they encounter in their daily lives, individuals with intellectual disabilities need support in the acquisition of these skills (Kim, 2010; Jang, Mehta, & Dixon, 2016). Studies show that individuals with disabilities learn to recognize, prevent and respond to potential emergencies and unsafe situations through systematic teaching (Matson, 1980; Haseltine &

Miltenberger, 1990; Mazzucchelli, 2001; Batu et al., 2004). However, it is seen that safety skills are not sufficiently included in children's IEPs due to some reasons stemming from families and teachers (thinking that they can be overcome with advice/protection, raising children overly dependent on the family, thinking that it is very difficult to learn these skills, insufficient knowledge about security skills, etc.) (Şirin, 2015). Pedestrian skills are one of the skills required for individuals with intellectual disabilities to lead their daily lives safely and to live independently in the community (Matson, 1980; Limbourg and Gerber, 1981; Katz et al. 2005). Individuals with mental disabilities who can walk safely on streets and avenues will be able to take an active role in society by functioning independently, such as doing their daily work, spending time with friends, and taking short trips in the city (Horner, Jones, & Williams, 1985; Mowafy & Pollack, 1995). However, there is a high risk for disabled people to take to the streets by relying on the experience and awareness of the drivers in order to teach in real environments. In particular, it is almost impossible to teach people with disabilities on roads with heavy traffic or at intersections (Matson, 1980).

Hundreds of thousands of traffic accidents occur every year in the world. Accordingly, pedestrians are also involved in traffic accidents and even lose their lives. In Turkey, the rate of death in pedestrian accidents is higher than in many European countries. A serious portion of fatal accidents occurs as a result of 'pedestrian collisions' and in 95% of these accidents, the drivers are at fault (Sungur et al., 2014). According to the data published by the Turkish Statistical Institute (TUIK), in 2020 there were 983,808 traffic accidents in the country. 150,275 of these accidents resulted in fatal injuries and 19.9% of those who lost their lives were pedestrians. 10.1% of the accidents resulting in injury occurred in traffic accidents involving pedestrians. In light of these data, many existing techniques and methods used for the teaching of pedestrian skills do not allow the repetitive applications needed for intellectually disabled children to cross the street safely. Virtual reality, on the other hand, allows practice repetitions in the skills to be taught, even in situations where teaching poses a risk (Schwebel & McClure, 2010). Adaptations to the street, pedestrian crossing, traffic light, and traffic density according to the cognitive characteristics of intellectually disabled children, provide the opportunity to increase the environmental reality (Josman et al., 2008; Wright & Wolery, 2011). Virtual reality applications eliminate all risks that may occur in the teaching of ethical and life-threatening skills. These applications can be easily applied in environments such as home and school and can be used safely in the teaching of critical skills such as fire, first aid, and pedestrian skills. When the literature is examined, it is seen that pedestrian skills are taught by using methods and environments such as video models, in-class adapted environments, public spaces (parking lots, closed roads, etc.), peer models, and question and answer (Page et al., 1976; Matson, 1980; Spears et al., 1981; Marchetti et al., 1983; Horner et al., 1985; Colins and Stinson, 1993; Branham et al., 1999; Batu et al., 2004). However, the techniques and methods used, do not provide the opportunity to adapt according to individual characteristics and frequent repetitions needed for the teaching of pedestrian skills. Virtual reality applications, on the other hand, eliminate all risks that may occur in the teaching of skills that carry ethical and vital risks. These applications can be easily applied in environments such as home and school and can be used safely in the teaching of critical skills such as fire, first aid, and pedestrian skills. Many security skills have been studied with different techniques and methods in the national and international literature, but the fact that these studies could not be taught in a realistic or real environment was included in the limitations of the research.

At this point, virtual reality applications can be designed with the images, and sounds of real environments and the people in those environments, without risk, and offer personalized experiences as close to reality. Therefore, this study will be a first in teaching pedestrian skills with virtual reality applications to intellectually disabled individuals and will make an important contribution to the literature.

Purpose

This research aims to determine the effects of virtual reality applications on teaching pedestrian skills to intellectually disabled children. Research questions for this general purpose are given below:

1.1. Are virtual reality applications effective in teaching children with intellectual disabilities the skill to cross the street using pedestrian crossing?
1.2. Are virtual reality applications effective in generalizing the ability of children with intellectual disabilities to cross the street using pedestrian crossing?
1.3. Can the behavior be maintained 1, 3, and 5 weeks after the end of teaching the skill of using pedestrian crossing to with intellectual disabilities children through virtual reality applications?
1.4. What are the views of parents and teachers on teaching children with mental disabilities the ability to cross the street using the pedestrian crossing with virtual reality applications?
2.1. Are virtual reality applications effective in teaching children with intellectual disabilities the skills to cross the street using the illuminated pedestrian crossing?
2.2. Are virtual reality applications effective in generalizing children with intellectual disabilities the skills to cross the street using the illuminated pedestrian crossing?
2.3. Can the behavior be maintained 1, 3, and 5 weeks after the end of teaching the skills to cross the street using the illuminated pedestrian crossing to children with intellectual disabilities through virtual reality applications?
2.4. What are the views of parents and teachers on teaching the skills to cross the street using the illuminated pedestrian crossing to children with intellectual disabilities with virtual reality applications?

Method

Research Model

In this study, the effectiveness of virtual reality applications in teaching pedestrian skills to mentally disabled children was examined. For this purpose, the multiple probe design with probe trials across participants, which is one of the single-subject research methods, was used. Experimental control in multiple probe designs is provided by a change in the data level or trend of the situation in which the application is made, no change in the data level or trends of the participants who have not yet been applied, and similarly, a similar change in the trend or level of the data occurs diachronically in the other participants as the application takes place (Tekin-İftar, 2012a). The dependent variable of this research is the increase in the acquisition level of pedestrian skills of children with intellectual disabilities. *The skills of crossing using the pedestrian crossing and crossing using the illuminated pedestrian crossing,* which are the pedestrian skills included in the study, were determined as a result of the literature review. *The skills of crossing the road using the overpass and crossing the road using the underpass*, which are among the other pedestrian skills planned to be studied, were excluded from the study's dependent variables, taking into account the city conditions in which the children live. Attention was paid to the fact that the dependent variables were independent from each other, but had functionally similar and close difficulty levels. For the analysis of pedestrian skills included in the study, expert opinion was obtained from two instructors who completed their Ph.D education in the field of special education.

Ethics Statement

Research ethics approval was obtained by Trakya University Social and Human Sciences Research Ethics Committee (Date: 20.10.2022/ Decision number: 08/03).

Table 1.
Crossing skill analysis using the pedestrian crossing

He/She comes to the pedestrian crossing.
He/she stops on the pavement before landing on the road.
He/she checks the road by looking to the left, then to the right, and again to the left.
If the vehicle is not coming or is too far away, He/she walks across the road.
When it reaches the middle of the road, He/she looks to the right again.
Walks quickly without running over the crosswalk lines.
He/she goes to the opposite sidewalk.

Table 2.
Crossing skill analysis using the illuminated pedestrian crossing

When coming to a pedestrian crossing with a pedestrian light, he/she stops two steps from the side of the road.
He/she looks at the traffic light.
If it is red, he/she waits.
When the green light is on, he/she looks to the left first and walks if the cars have stopped.
When he/she comes to the middle of the road, he/she looks to the right again.
He/she goes to the opposite sidewalk.

The independent variable of the research is the teaching application presented with virtual reality glasses. Virtual reality is defined as the technology that enables people to interact with these objects in the environment, as well as giving the feeling of being in a real environment in the minds of people with 3D pictures and animations created in the computer environment (Çavaş et al., 2004).

Participants

Participants in the study were determined as a result of interviews with teachers and their families. In the interviews, the prerequisite skills that the participants to take part in the research process should have were specified, and 3 participants who could take part in the study were determined in line with these skills. Some prerequisite skills were sought in the participants in the study. These prerequisite skills are: a) to be diagnosed with intellectual disability, b) to have no visual impairment, c) to have gross motor skills such as walking, running, jumping, and turning one's head left and right, d) to be able to correctly follow instructions that state two actions, e) during the virtual reality application, the participants know the concepts of place and direction and the colors in the traffic light so that they can position themselves in the virtual environment and feel the sense of direction, f) be able to direct the attention of the participants to the video images in the virtual reality glasses.

Table 3.
Characteristics of the students participating in the research

Student	Age	Gender	Diagnosis
Özge	15	Female	mental disability
Elif	14	Female	mental disability
Cemil	11	Male	mental disability

Setting

The applications were carried out in the drama hall and the researcher's room in the same building. The pilot application of the research was carried out in the special education and rehabilitation center where the participants attended. The starting level of the research, the implementation, and the follow-up sessions were held in the drama hall and the researcher's room. Generalization sessions were conducted in real environments, on roads closed to traffic with real pedestrian crossings and traffic lights.

Tools

For the virtual reality application, which is the independent variable of the research, Bobo VR Z4 and Bobo VR Z5 virtual reality glasses were used. The reason for choosing the glasses used is that they are light and have a built-in speaker system. The virtual reality glasses used offer an immersive viewing angle of up to 120 degrees. In addition, control devices that enable Bluetooth connection with smartphones or computers were purchased together with the glasses.
The virtual reality application, which includes the pedestrian skills to be taught, is the training application program prepared for pedestrian safety training called Crosswalk VR App 1. The application consists of three-dimensional spatial images required for users to cross the street and allows the implementation to be made without actually going out on the street. In order to process the responses of the participants in the Crosswalk VR App 1 application to the data recording form, the images must be transferred to the interface on the computer. Wi-Fi connection was sometimes used for this process, but there were problems in image transmission due to the variability in internet quality, and after a few implementations, the data was sent to the interface on the computer only with the help of data transfer cables.
Basically, this process is mandatory for the practitioner to see the environment seen by the participant, for the reactions to be recorded on the registration form, and for error corrections. This process was used to see and record the reactions of the participants while wearing the virtual reality glasses with the Crosswalk VR App 1 application. A program or interface through which images are transferred and the user can see participant reactions is essential for application reliability. For this process, a program which is called Vysor was purchased and used with its license. The Vysor program is used to send the image on the smartphone or computer to the desired vehicle with high resolution. The program also transfers the sound along with the image and allows the recording of data in real time. As explained in the previous paragraphs, a connection can be established with the help of Wi-Fi, a Web Port, or a data cable.

Table 4.
List of tools used in the research

Laptop	Virtual reality pedestrian app
Desktop	Data transfer cable x 2 (3 meters)
Camera	3D image transfer program - Vysor
Smartphone	Internet connection/Wi-Fi
Virtual reality glasses x 2	Initiation/implementation/monitoring data forms
Virtual reality controller x 2	

Pilot Study

A pilot study was conducted in order to determine the problems that may be experienced in the functioning of the dependent and independent variables, the tools and data forms to be used at the beginning, probe, teaching, and follow-up phases of the study, and to solve them beforehand. The pilot study was carried out with the teaching procedure and tools to be followed during the experiment. The study was carried out with a student who had the prerequisite skills of the students who would participate in the experiment process.

The pilot study was carried out in the special education and rehabilitation center where the determined student was educated. Permission for the study was obtained from the student's institution director, teacher, and parents. The study lasted two days, with a total of five beginning levels and five practice sessions. The laptop to be used during the application, virtual reality glasses, control devices, Crosswalk VR application, data cables, Vysor interface program, the responses of the participants when the virtual reality glasses are put on and off, and data collection forms were tested.
On the first day of the pilot study, there were technical problems in transferring data from the virtual reality glasses to the computer screen. This situation prevented the practitioner from properly processing student responses into the data recording form and systematically using the reinforcer schedule. In addition, the student had difficulty in establishing the relationship between the virtual

reality glasses and the control device. This situation was associated with not giving enough information to the student during the presentation of the materials. In the sessions on the second day, the problem of data transfer to the computer screen was solved with the help of data cables with a length of 3 meters and a data transfer capacity of 480 Megabits/second. The solution to the data transfer problem enabled the practitioner to collect data in accordance with the procedure and to use the reinforcer schedule within the specified criteria. In addition, allowing the participant to play the games downloaded from the Google App with the virtual reality glasses and controller at the beginning of the second day helped the participant to recognize the devices and eliminated the problems experienced during the application phase.

Experimental Process

The entire experimental process was carried out by the researcher through one-on-one teaching. Sessions were held within the scope of Covid-19 importance. Within the scope of social distance, mask, and hygiene rules, the practice environment was ventilated before and after the teaching sessions, the hands were disinfected before the students were taken to the practice environment and they were not allowed to remove their masks. After the teaching sessions, the hands of the students were disinfected and their masks were changed. The same disinfection processes were carried out for the materials used. In addition, students were not allowed to use public transportation vehicles on their arrival and departure, they were taken from their homes at the specified times with the knowledge of the families and left at the end of the application in the same way.

Before starting the research, verbal and written permission was obtained from the families of the participants regarding data collection and camera shooting. For the teaching of the dependent variable, three days a week, Friday, Saturday, and Sunday, were studied and three teaching sessions were held each day. The probe sessions were taken just before the fourth teaching session, after the three teaching sessions.

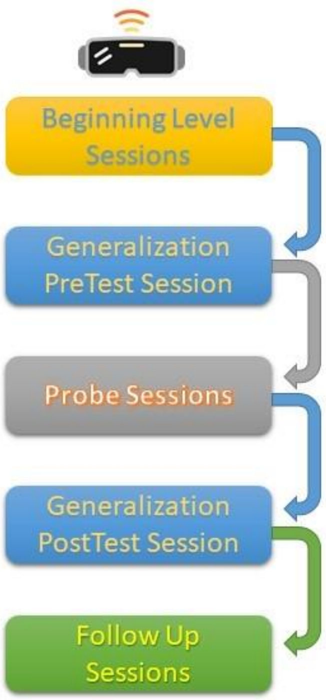

Figure 1. The Implementation Procedure to Be Repeated for Each Participant

After the first of the beginning level session were held with all three of the participants, the second and third sessions of the beginning level session were also taken with the first participant. After the beginning level session of the first participant was completed, a generalization pre-test session was held and then teaching sessions and intermittent probe sessions were started. Intermittent probe sessions were held after each of the three teaching sessions. After the first probe session, in which the first participant gave a 100% correct response, probe sessions were held for the other two participants.

When the first participant gave a 100% correct response in three consecutive sessions, the teaching sessions were terminated and a generalization post-test session was held. Follow-up sessions were held one, three, and five weeks after the generalization post-test sessions. The experimental process of the research continued from the first beginning level session to the last follow-up session for the first participant and lasted for three months.

Beginning Level and Intermittent Probe Sessions

After preparing the environment and tools for the beginning level and intermittent probe sessions, the sessions were held. Beginning level sessions were continued until stable data were obtained for three consecutive sessions in all participants. During the sessions, the participant's attention to the practice and the researcher was reinforced, but after the skill instruction was given, the reinforcer was not presented. At the beginning level and intermittent probe sessions, the Crosswalk VR application was opened to the participants through virtual reality glasses, and skill instruction was presented (Crosswalk). In this process, the single opportunity method was used and if the participant could not perform one of the skill steps, the trial was terminated and the next trial was started.

Teaching/Implementation Sessions

The participants were taken to the teaching sessions after all the necessary preparations were completed and the environment and equipment were ready. The attention-provoking stimulus was presented to the participants ('Hello Özge, are you ready to work with me today?', 'Cemil, are you ready to work with virtual reality glasses today?'). It is Reinforced when the student stated that he/she was ready verbally or with facial expressions ("Great, then let's put on the virtual reality glasses and get to work.'). After the virtual reality glasses were put on the participant properly, the image on the interface was checked from the computer (this process takes an average of six seconds) and the skill instruction was presented.

Generalization Sessions

In the study, generalization sessions were conducted to determine the level of generalization of the skills learned by the participants to different people, environments, and tools. Generalization sessions were held as pre-test generalization sessions after beginning level data were collected, and post-test generalization sessions after the teaching sessions were completed. The generalization data of the skills of *crossing using the pedestrian crossing and crossing using the illuminated pedestrian crossing*, which are the dependent variables of the study, were carried out in real pedestrian crossings and illuminated pedestrian crossings. One more adult attended the sessions to provide assistance and safety to the practitioner. In addition, the names in the study are not the real names of the participants.

Follow-up Sessions

After the participants completed the teaching sessions, follow-up sessions were held to determine to what extent they were able to demonstrate the skills they learned. Follow-up sessions were held one, three, and five weeks after the end of the instruction.

Inter-Observer Confidence Data

In the study, inter-observer reliability data, the "consensus / (consensus + disagreement) x 100" formula was used. Consensus and disagreement will be calculated together with the data recording forms to be filled in by the observers and the data collected by the researcher (Tekin-İftar and Kırcaali-İftar, 2012).

Inter-observer reliability data were collected and analyzed from 30% of all sessions regarding the beginning level, teaching, probe, generalization, and follow-up sessions conducted in the study. Inter-observer reliability data for all phases of the study are shown in Table 5.

Table 5.
Inter-observer reliability findings for all participants and stages regarding teaching pedestrian skills with virtual reality application

Participant	Beginning Level	Teaching	Probe	Follow-up	Overall Average
Özge	100%	100%	100%	100%	100%
Elif	100%	100%	100%	100%	100%
Cemil	100%	100%	100%	100%	100%

Social Validity Data

At the end of the study, social validity questionnaires prepared by the researcher were applied to the participants and their mothers. In the forms, questions about the dependent and independent variables were asked and the answers were recorded. There are nine closed-ended questions in both forms prepared for the participants and mothers, and they were asked to choose one of the options yes, no, or undecided in response to these questions.

Table 6.
Social validity data form for participants

Questions	f	Yes %	No %	Undecided %
1. Do you enjoy learning things using Virtual Reality glasses?	3	100	0	0
2. Did you enjoy learning pedestrian skills?	3	100	0	0
3. Did you enjoy learning to cross the street using the pedestrian crossing?	3	100	0	0
4. Did you enjoy learning to cross the street using a traffic light?	3	100	0	0
5. Would you like to participate in such a study again?	3	100	0	0
6. Do you want your teachers or parents to work with you with Virtual Reality glasses?	3	100	0	0
7. Can you cross the crosswalk on your own?	3	100	0	0
8. Can you cross by yourself using the traffic light?	3	100	0	0
9. Do you want your friends to learn what you learned?	3	100	0	0

Table 7.
Social validity data form for mothers

Questions	f	Yes %	No %	Undecided %
1. Do you think safety skills are important skills for your children?	2	100	0	0
2. Do you think pedestrian skills are important skills for your children?	2	100	0	0
3. Have you tried teaching your child pedestrian skills?	2	0	100	0
4. Do you like the use of Virtual Reality for teaching pedestrian skills to your child?	2	100	0	0
5. Have you ever used Virtual Reality applications for entertainment or trial purposes with your child?	2	0	100	0
6. Have you ever used Virtual Reality applications to teach your child?	2	0	100	0

Table 7 continuing

7. Have you ever thought that you can teach your child with Virtual Reality glasses?	2	0	100	0
8. Do you think Virtual Reality applications are effective in teaching pedestrian skills?	2	100	0	0
9. Would you prefer to use Virtual Reality applications to teach your children?	2	100	0	0

Findings

Figure 2 and Figure 3 show the graphics of the students participating in the study on teaching the skills of crossing using the pedestrian crossing and using the illuminated pedestrian crossing with a virtual reality application. Data for each student and skill are shown in a line chart. The horizontal axis in the line graph shows the number of sessions, and the vertical axis shows the correct response percentages of the participants. The line chart contains data for beginning, probe, and Follow-up sessions.

Findings on the teaching of crossing skills using the pedestrian crossing with virtual reality application

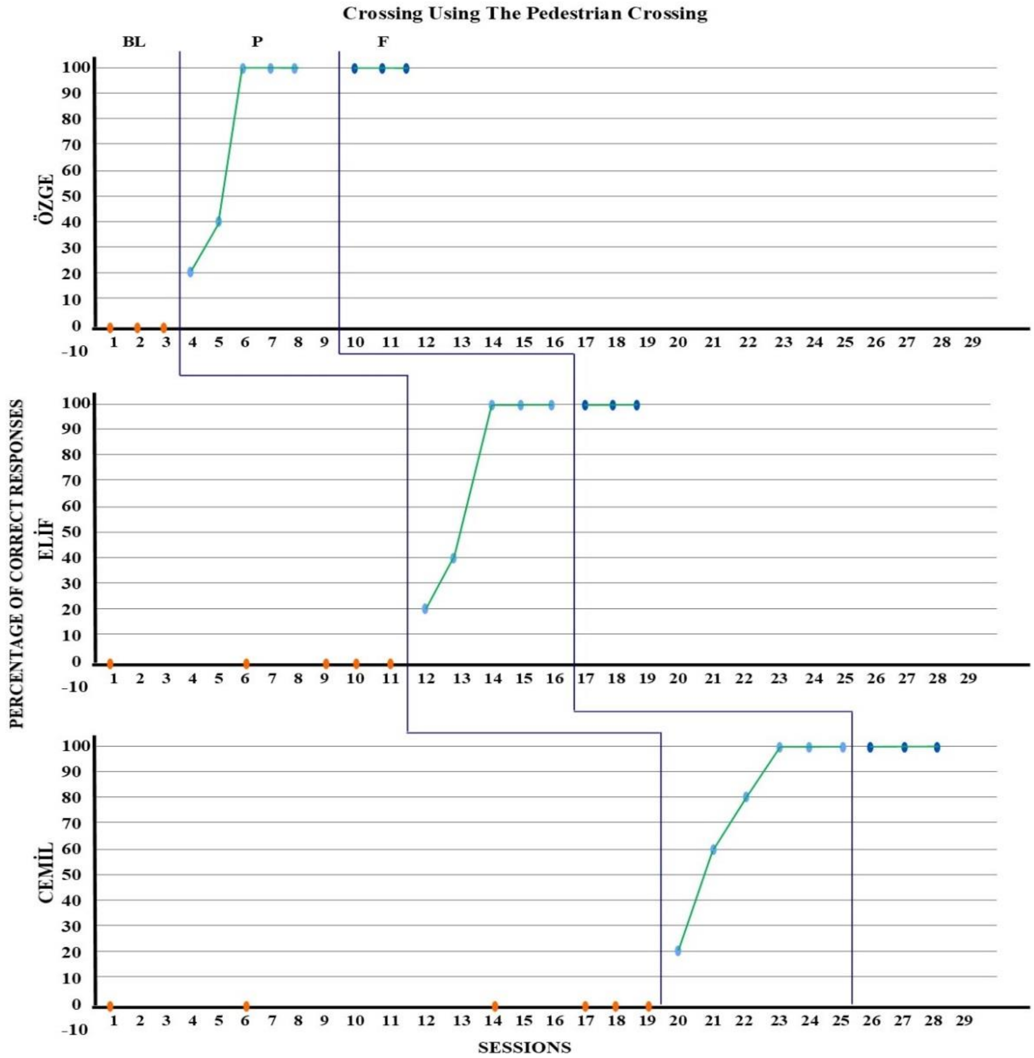

Figure 2. The correct response percentages in Özge, Elif, and Cemil crossing using the pedestrian crossing in the beginning level (BL), probe (P), and follow-up session (F).

The data obtained at the beginning level, probe, and follow-up phases regarding Özge's ability to cross the street using the pedestrian crossing are given in Figure 2. As seen in the graph, Özge's average performance at the beginning level stage (0%, 0%, 0%) is 0%. After stable data were obtained at the beginning level stage, the implementation stage was started. In the first probe sessions taken during the implementation phase, 20% correct response percentage and 40% correct response percentage are seen in the second. In the third, fourth, and fifth probe sessions, it is seen that the 100% criterion was reached.

In the follow-up phase, when the criteria set in the implementation phase were met with the participant, it was examined whether the permanence effects of the teaching continued after 1, 3, and 5 weeks. It is seen that Özge continued to demonstrate the skill with 100% accuracy in all three follow-up sessions. This shows that the participant continues to exhibit the skill after the training is over.

The data show that Özge started to demonstrate her ability to cross the street using the pedestrian crossing with 100% accuracy at the end of six teaching sessions. Each point in the implementation phase represents three teaching sessions. 15 teaching sessions were held with Özge until the criterion was met and these sessions lasted for a total of 18.75 minutes.

The data obtained at the beginning level, probe, and follow-up phases regarding Elif's ability to cross the street using the pedestrian crossing are given in Figure 2. As seen in the graph, the average performance of Elif at the beginning level stage (0%, 0%, 0%, 0%) is 0%. When the criterion was met in the implementation phase with Özge, three more beginning-level sessions were held consecutively with Elif, the second participant, until stable data were obtained. After stable data were obtained at the beginning level stage, the implementation stage was started. Elif has a correct response rate of 20% in the first probe session and 40% in the second probe session. In the third, fourth, and fifth probe sessions, it was seen that Elif met the 100% criterion.

In the follow-up phase, when the criteria set in the implementation phase were met with the participant, it was examined whether the permanence effects of the teaching continued after 1, 3, and 5 weeks. It is seen that Elif continued to demonstrate the skill with 100% accuracy in all three follow-up sessions. This shows that the participant continues to exhibit the skill after the training is over.

The data show that Elif started to demonstrate her ability to cross the street using the pedestrian crossing with 100% accuracy at the end of six teaching sessions. Each point in the implementation phase represents three teaching sessions. 15 teaching sessions were held with Elif until the criterion was met and these sessions lasted for a total of 18.75 minutes.

The data obtained at the beginning level, probe, and follow-up phases regarding Cemil's ability to cross the street using the pedestrian crossing are given in Figure 2. As seen in the graph, the average performance of Cemil at the beginning level stage (0%, 0%, 0%, 0%, 0%) is 0%. When the criteria were met in the implementation phase with Elif, three more beginning-level sessions were held with Cemil, the third participant, in succession, until we obtained stable data. After stable data were obtained at the beginning level stage, the implementation stage was started. Cemil has a correct response percentage of 20% in the first, 60% in the second, and 80% in the third probe session taken during the implementation phase. In the fourth, fifth, and sixth probe sessions, it was seen that Cemil met the 100% criterion.

In the follow-up phase, when the criteria set in the implementation phase were met with the participant, it was examined whether the permanence effects of the teaching continued after 1, 3, and 5 weeks. It is seen that Cemil continued to demonstrate the skill with 100% accuracy in all three follow-up sessions. This shows that the participant continues to demonstrate the skill after the training is over.

The data show that Cemil started to demonstrate his ability to cross the street using the pedestrian crossing with 100% accuracy at the end of nine teaching sessions. Each point in the implementation phase represents three teaching sessions. 18 teaching sessions were held with Cemil until the criterion was met and these sessions lasted a total of 22.5 minutes.

Findings on teaching the skill to cross the street using the illuminated pedestrian crossing with virtual reality application

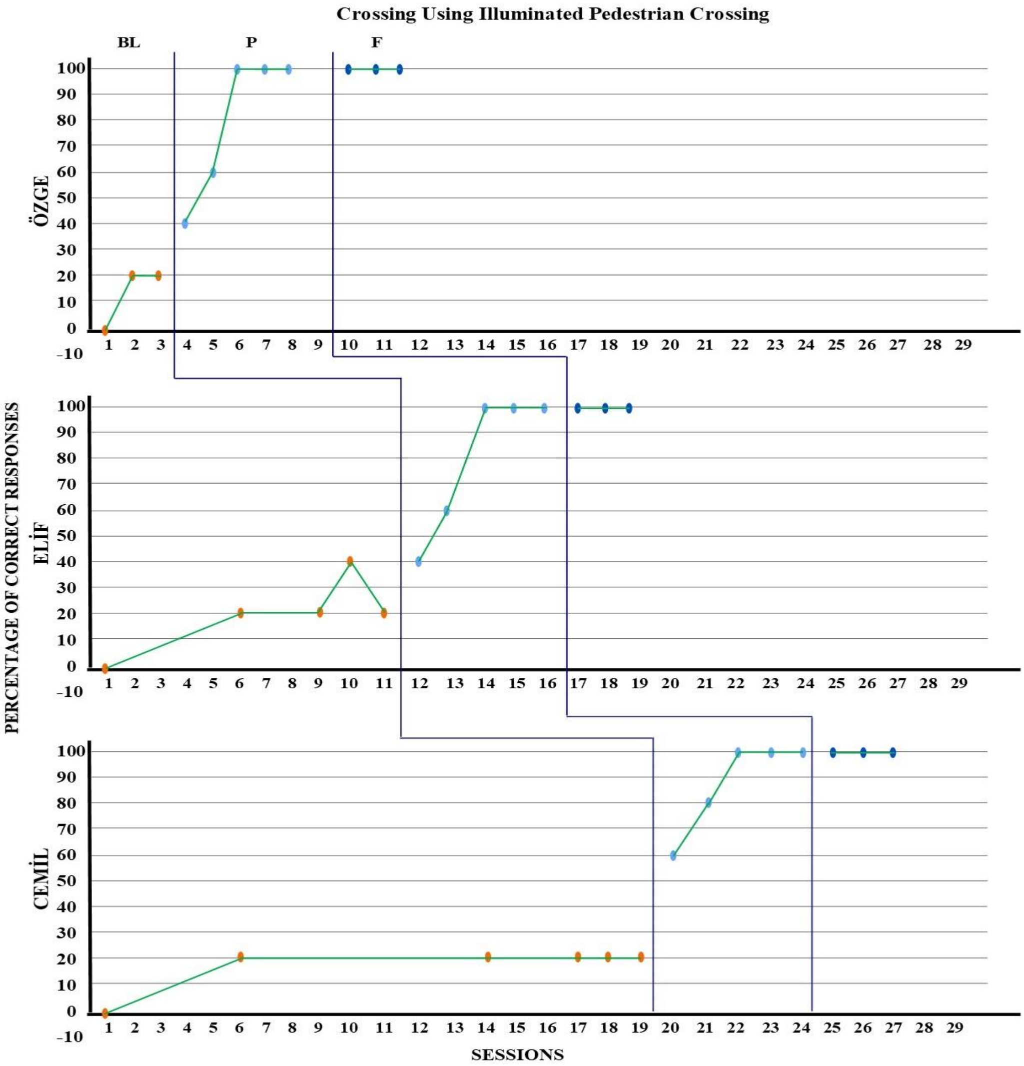

Figure 3. The correct response percentages in Özge, Elif, and Cemil crossing using an illuminated pedestrian crossing in the beginning level (BL), probe (P), and follow-up session (F).

The data obtained at the beginning level, probe, and follow-up phases regarding Özge's skill to cross the street using the illuminated pedestrian crossing are given in Figure 3. As seen in the graph, Özge's average performance at the beginning stage (0%, 20%, 20%) is 13.3%.

After stable data were obtained at the beginning stage, the implementation stage was started. In the first probe sessions taken during the implementation phase, 40% correct response percentage, in the second, 60% correct response percentage are observed. In the third, fourth, and fifth probe sessions, it is seen that the 100% criterion was reached.

In the follow-up phase, when the criteria set in the implementation phase were met with the participant, it was examined whether the permanence effects of the teaching continued after 1, 3, and 5 weeks. It is seen that Özge continued to demonstrate her skill to cross the street using the illuminated pedestrian crossing with 100% accuracy in all three follow-up sessions. This shows that the participant continues to demonstrate the skill after the training is over.

The data show that Özge started to demonstrate the skill to cross the street using the illuminated pedestrian crossing with 100% accuracy at the end of six teaching sessions. Each point in the implementation phase represents three teaching sessions. 15 teaching sessions were held with Özge until the criterion was met and these sessions lasted a total of 21 minutes.

The data obtained at the beginning level, probe, and follow-up phases regarding Elif's ability to cross the street using the pedestrian crossing are given in Figure 3. As seen in the graph, the average performance of Elif at the beginning level stage (0%, 20%, 20%, 40%, 20%) is 20%. When the criterion was met in the implementation phase with Özge, three more beginning-level sessions were held consecutively with Elif, the second participant, until stable data were obtained. After stable data were obtained at the beginning level stage, the implementation stage was started. Elif has an accurate response rate of 40% in the first probe session and 60% in the second probe session. In the third, fourth, and fifth probe sessions, it was seen that Elif met the 100% criterion.

In the follow-up phase, when the criteria set in the implementation phase were met with the participant, it was examined whether the permanence effects of the teaching continued after 1, 3, and 5 weeks. It is seen that Elif continued to demonstrate her skill to cross the street using the illuminated pedestrian crossing with 100% accuracy in all three follow-up sessions. This shows that the participant continues to demonstrate the skill after the training is over.

The data show that Elif started to demonstrate her ability to cross the street using the pedestrian crossing with 100% accuracy at the end of six teaching sessions. Each point in the implementation phase represents three teaching sessions. Until the criterion was met with Elif, 15 teaching sessions were held and these sessions lasted for a total of 21 minutes.

The data obtained at the beginning, probe, and follow-up phases regarding Cemil's skill to cross the street using the illuminated pedestrian crossing are given in Figure 3. As seen in the graph, the average performance of Cemil at the beginning stage (0%, 20%, 20%, 20%, 20%, 20%) is 16.7%. When the criteria were met in the implementation phase with Elif, three more beginning sessions were held with Cemil, the third participant, in succession, until we obtained stable data. After stable data were obtained at the beginning stage, the implementation stage was started. Cemil has an accurate response rate of 60% in the first probe session and 80% in the second probe session. In the third, fourth, and fifth probe sessions, it was seen that Cemil met the criterion of 100%.

In the follow-up phase, when the criteria set in the implementation phase were met with the participant, it was examined whether the permanence effects of the teaching continued after 1, 3, and 5 weeks. It is seen that Cemil continued to demonstrate his skill to cross the street using the illuminated pedestrian crossing with 100% accuracy in all three follow-up sessions. This shows that the participant continues to demonstrate the skill even after the training is over.

The data show that Cemil started to demonstrate his ability to cross the street using the pedestrian crossing with 100% accuracy at the end of nine teaching sessions. Each point in the implementation phase represents three teaching sessions. 15 teaching sessions were held with Cemil until the criterion was met, and these sessions lasted for a total of 21 minutes.

In this study, generalization sessions were conducted to determine the level of generalization of the skills learned by the participants to different people, environments, and tools. Generalization sessions were held as pre-test generalization sessions after introductory data were collected, and post-test generalization sessions after the teaching sessions were completed. The generalization data of the skills of *crossing using the pedestrian crossing and crossing using the illuminated pedestrian crossing*, which are the dependent variables of the study, were carried out in real pedestrian crossings and illuminated pedestrian crossings. One more adult attended the sessions to provide assistance and safety to the practitioner. In addition, the names in the study are not the real names of the participants.

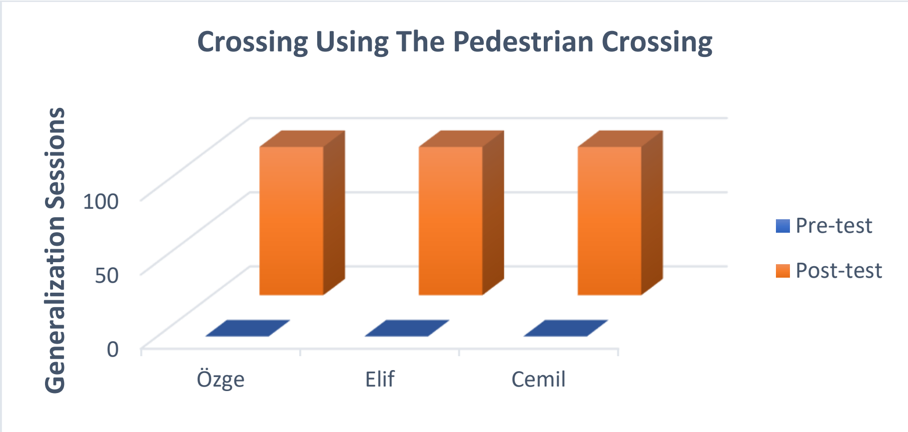

Figure 4. Generalization Percentages of Özge, Elif, And Cemil's Performances of Crossing Using The Pedestrian Crossing.

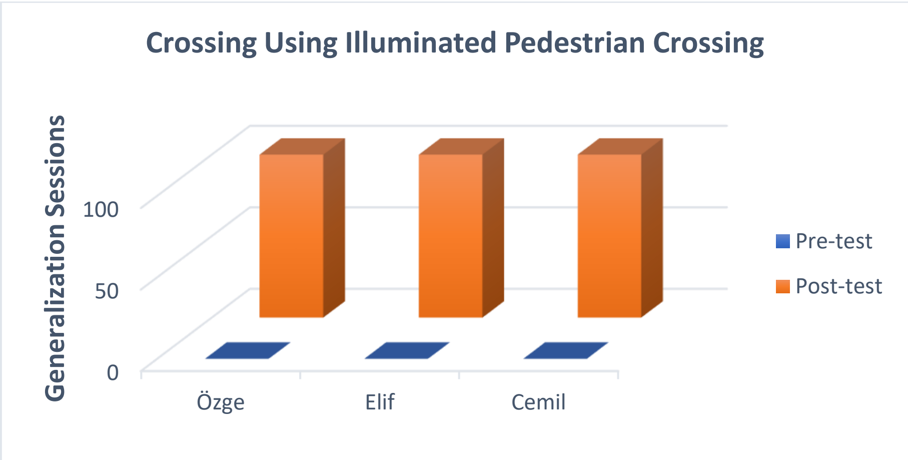

Figure 5. Generalization Percentages of Özge, Elif, And Cemil's Performances of Crossing Using The Illuminated Pedestrian Crossing

Discussion, Conclusion, And Recommendations

In this study, the effects of virtual reality applications on teaching pedestrian skills were determined. In addition, the effects of follow-up and generalization regarding dependent and independent variables were also determined in the study. Within the scope of the study, the skills of using pedestrian crossing and crossing using traffic lights were taught. One of the skills determined during the planning process of the study, *the ability to cross using the overpass*, was excluded from the skills to be studied by considering the conditions of the city of Edirne where the participants lived. The absence of an overpass in urban conditions eliminates the possibility of generalizing the skill and using it after the teaching is completed. For this reason, the researcher decided to exclude this skill from the study.

Research findings show that city simulation presented with virtual reality applications is effective in teaching the skills of crossing using the pedestrian crossing and crossing using traffic lights. Follow-up sessions held 1, 3, and 5 weeks after the teaching of the skills show that the skills are preserved. In addition, it is seen that the participants exhibited these skills with 100% accuracy in the real environment pedestrian crossing and illuminated pedestrian crossing in the environment generalization post-test sessions organized for pedestrian skills taught with virtual reality simulation. Within the scope of the study, the opinions of the participants and their mothers on the implementation and results were taken. Obtaining the opinions of the participants and determining their subjective opinions about the study within the studies carried out with individuals with special needs is one of the important and strong aspects of this research. The mothers stated that they were satisfied with the teaching of pedestrian skills with the results of the study and the virtual reality application and that similar applications could be used for their children in the next teaching processes. The basis of the positive opinions of mothers about virtual reality technology is that they think that this technology is for gaming and they are unaware of its use for educational purposes. Participants, on the other hand, stated that they were impressed by the fact that virtual reality technology is an interesting and new technology and the feeling of being in the same place with the practitioner but in different environments. This situation has caused the technology used to be an extra source of motivation for teaching.

Most of the studies on teaching pedestrian skills or skill groups including pedestrian skills with virtual reality applications have been carried out with individuals with autism (Goldsmith, 2008; Josman, 2008; Saiano, 2015a; Saiano, 2015b; Tzanavari et al., 2015; Peng et al., 2018; Dixon et al. et al., 2019). On the other hand, Cherix and his friends (2020), taught the ability to cross the street in different conditions such as weather, driver attitudes, night and day in their experimental study with 15 intellectually disabled children, however, while teaching this skill, they examined the participants' passing times and how long they reacted to the situations they encountered while crossing, rather than their acquisition.

When the beginning level and generalization pre-test data of the first participant Özge's ability to cross the street using the pedestrian crossing are examined, it is seen that she gave 0% correct response in all sessions. During the pilot study, it was determined that the children should spend time with the materials and get used to the materials, and even though this process was run for all the participants, the reason why Özge did not respond correctly at the beginning level can be explained by the fact that she was not used to the virtual reality glasses and the feeling of reality she lived. After the beginning sessions were completed, the teaching phase was started, and when the three teaching sessions were completed, a probe session was held before the fourth teaching session. It is seen that Özge gave a 20% correct response in the first probe session. It was observed that Özge had difficulties in the steps *'She stops on the pavement before getting down to the road, she checks the road by looking first to the left, then to the right and then to the left'.* After Özge got off the pavement, she checked her left and right, thus preventing her from performing the skill. A similar situation occurred in the study of Tzanavari and his friends (2015), and students made a timing error while checking their left and right. Özge gave a 100% correct response in the third probe session and maintained this performance in the following two probe sessions. This efficacy data is similar to the results of other studies in the literature (Goldsmith, 2008; Josman, 2008; Saiano, 2015a; Tzanavari et al., 2015; Peng et al., 2018; Dixon et al., 2019). Teaching sessions with Özge and other participants consisted of five trials. The factors that may cause the sessions to be prolonged have been controlled beforehand since there are VR teaching sessions lasting 45 minutes in the literature (Saiano, 2015a), and wearing virtual reality glasses for a long time will tire the eyes of the children and negatively affect the experimental process of the study. The sessions did not last long, as the ability to cross the street using the pedestrian crossing occurred in the range of 8-15 seconds. In addition, 60 minutes was put between each teaching session in all skills to prevent the carrier effect. It was observed that the skills continued in the follow-up sessions, which were held 1, 3, and 5 weeks after the stable data were obtained in the probe sessions, similar to other studies in the literature (Tzanavari et al., 2015; Dixon et al., 2019). When the Generalization Pre-Test and Post-Test data are examined in Figure 4, it is seen that Özge generalizes the skill she learned with the VR application to the real environment.

When Özge's skill to cross the street using the illuminated pedestrian crossing lights beginning data is examined, it is seen that she gave 0% correct response in the first session and 20% correct response in the next two sessions. When Özge's beginning data in the first skill were examined, it was seen that she gave 0% correct response, but she gave 20% correct response in the second and third beginning sessions of the second skill. This situation shows that Özge carries the knowledge she gained in teaching the skill of crossing using the pedestrian crossing to the skill to cross the street using the illuminated pedestrian crossing, and that is, there is a carrier effect. However, this effect is low. In the Generalization Pre-Test session Figure 5, it is seen that Özge gave 0% correct response. After the beginning level sessions were completed, the teaching phase was started. It is seen that Özge responded correctly to 40% in the first probe session and 60% in the second probe session. It has been observed that Özge has difficulties in the skill level of "If it's red, wait; When it turns green, first look to the left. If the cars have stopped, look to the right when she reaches the middle of the road". Özge tried to cross the street without paying attention to the traffic lights or tried to cross at the red light. Özge gave a 100% correct response in the third probe session and maintained this performance in the following two probe sessions. This efficacy data is similar to the results of other studies in the literature. It was observed that the skills continued in the follow-up sessions, which were held 1, 3, and 5 weeks after stable data were obtained in the probe sessions, similar to other studies in the literature (Tzanavari et al., 2015; Dixon et al., 2019). When the Generalization of the Pre-Test and Post-Test data are examined in Figure 5, it is seen that Özge generalizes her skill to cross the street using the illuminated pedestrian crossing she learned through the VR application to the real environment.

The first beginning level of the second participant, Elif's ability to cross the street using the pedestrian crossing, is a collective probe session with all participants. The second probe session is the second full probe session due to the first probe session in which Özge responded 100% correctly. A total of five probe sessions, together with the three beginning sessions, were held with Elif before starting the teaching, and she gave 0% correct response in these sessions. The 0% correct response rate in these sessions can be explained by the fact that she is not used to the virtual reality glasses and the feeling of reality she experiences, in the same way as Özge. When the teaching session with Elif is started, it is seen that she gave a 20% correct response in the first probe session. It was observed that Elif had difficulties with the first participant Özge, in the skill step, *'stop on the pavement before getting down on the road, check the road by looking first to the left, then to the right and then to the left'*. Elif gave a 100% correct response in the third probe session and maintained this performance in the following two probe sessions. This efficacy data is similar to the results of the previous participant and other studies in the literature. In the follow-up sessions held 1, 3, and 5 weeks after the stable data were obtained in the probe sessions, it was observed that the skills continued, similar to the previous participant and other studies in the literature. When Generalization the Pre-Test and Post-Test data are examined in Figure 4, it is seen that Elif generalizes the skill she learned with the VR application to the real environment.

The first beginning level of Elif's skill to cross the street using the illuminated pedestrian crossing is a collective probe session with all participants. The second probe session is the second full probe session due to the first probe session in which Özge responded 100% correctly. When the beginning data of Elif are examined, it is seen that she gave 0% correct response in the first session, and 20%, 20%, 40%, and 20% correct response in the following sessions, respectively. The 0% beginning data in the first session can be explained as the effect of the information in the teaching of the ability to adapt to the new skill and the data in the following sessions, using the pedestrian crossing, carried over to this skill. Similar to the first participant Özge, it is seen that Elif gave a correct response of 40% in the first probe session and 60% in the second probe session. It has been observed that Elif has difficulties in the steps of *"When green lights up, look left first if the cars have stopped, walk, look right when comes to the middle of the road"*. Elif tried to cross the street when the traffic light turned green, but she did not turn to her left and check that the cars had stopped. Elif gave a 100% correct response in the third probe session and maintained this performance in the following two probe sessions. This efficacy data is similar to the results of the first participant Özge and other studies in the literature. In the follow-up sessions held 1, 3, and 5 weeks after the stable data were obtained in the probe sessions, it was observed that the skills continued, similar to the first participant Özge and other studies in the literature. When Generalization the Pre-Test and Post-Test data are examined in Figure 5, it is seen that Elif generalizes her skill to cross the street using the illuminated pedestrian crossing that she learned with the VR application.

The first beginning level of the third participant, Cemil's ability to cross the street using the pedestrian crossing, is a collective probe session with all participants. The second probe session is the collective probe session held because of the first probe session where Özge responded 100% correctly and the third probe session was the first probe session where Elif responded 100% correctly. A total of six probe sessions were held with Cemil, with three beginning sessions taken before the teaching. Cemil gave 0% correct response in all of these sessions. The 0% correct response rate in these sessions can be explained by the fact that he is not accustomed to the virtual reality glasses and the feeling of reality he experiences, the same as the other two participants. When the teaching session with Cemil was started, it was seen that he gave a 20% correct response in the first probe session. It was observed that Cemil had difficulties in the steps of *" stop on the pavement before getting down on the road, check the road by looking first to the left, then to the right and then to the left, and when reaching the middle of the road, look to the right again"*. Unlike the other participants, Cemil gave a 100% correct response in the fourth probe session and continued this performance in the next two probe sessions. To meet the criteria, Cemil received three more teaching sessions, i.e. one probe session, than the other participants. This efficacy data is similar to the results of previous participants and other studies in the literature. In the follow-up sessions held 1, 3, and 5 weeks after the stable data were obtained in the probe sessions, it was observed that the skills continued, similar to the previous participants and other studies in the literature. When Generalization the Pre-Test and Post-Test data are examined in Figure 4, it is seen that Cemil generalizes the skill he learned with the VR application to the real environment.

The first beginning level of Cemil's skill to cross the street using illuminated pedestrian crossing is a full probe session with all participants. The second probe session is the collective probe session held because of the first probe session where Özge responded 100% correctly and the third probe session was the first probe session where Elif responded 100% correctly. A total of six probe sessions were held with Cemil, with three beginning sessions taken before the teaching. It is seen that Cemil gave a 0% correct response in the first beginning session and gave 20%, 20%, 20%, and 20% correct responses in the following sessions, respectively. When the beginning data on Cemil's skill to cross the street using illuminated pedestrian crossing are examined, it is seen that there is not any transport effect from the other probes. It is seen that Cemil, unlike the other participants, gave a 60% correct response in the first probe session. Although this situation creates the suspicion of immediate effect, an 80% correct response percentage in the next session can be interpreted as no immediate effect. However, the knowledge that Cemil gained in the ability to cross the street using the pedestrian crossing may have been transferred to this skill and an acceleration that increased from 16.7% to 60% correct response, which was the average of the beginning sessions, could be observed. It was observed that Cemil had difficulties in the last step of the skill analysis, *'when reaching the middle of the road, look to the right'*. Cemil correctly performed the part of the last step of the skill, *'When the green light comes on, look to the left first and walk if the cars have stopped'*, but in the second part of the step, *'look to the right when reaching the middle of the road'*, he crossed the road without checking the cars. Similar to other participants, Cemil gave a 100% correct response in the third probe session and continued this performance in the following two probe sessions. This efficacy data is similar to the results of other participants and other studies in the literature. In the follow-up sessions held 1, 3, and 5 weeks after the stable data were obtained in the probe sessions, it was observed that the skills continued, similar to the other participants and other studies in the literature. When Generalization the Pre-Test and Post-Test data are examined in Figure 5, it is seen that Cemil generalizes the skill to cross the street using the illuminated pedestrian crossing he learned with the VR application to the real environment.

As a result, virtual reality application is effective in gaining pedestrian skills for intellectually disabled children and maintaining them for 1, 3, and 5 weeks after the end of education. In addition, it was emphasized that it is important to generalize the skills to the real environment in all of the studies in which pedestrian skills are taught with virtual reality applications (Goldsmith, 2008; Josman, 2008; Saiano, 2015; Tzanavari et al., 2015; Peng et al., 2018; Dixon et al., 2019). In some studies, generalizations could not be made in real environments due to the vital risks and ethical concerns that may be experienced in traffic (Goldsmith, 2008; Tzanavari et al., 2015). Goldsmith (2008) stated in his study that these skills can be taught with virtual reality applications, but at the generalization stage, the participants could not generalize the skills to the real environment. One of the important data that this study adds to the literature is that pedestrian skills taught with virtual reality applications have been generalized to real environments with a 100% correct response. The present study shows that life-threatening safety skills such as pedestrian skills can be taught to individuals with special needs with virtual reality applications and can be generalized to real environments.

According to the results of the study, suggestions for future studies are listed below.

1. Studies can be carried out with more heterogeneous participant groups regarding the teaching of pedestrian skills with virtual reality applications.

2. While determining the pedestrian skills to be taught with virtual reality applications, the skills of using overpasses and underpasses can be included in the studies.

3. In addition, skills related to traveling and urban transportation can be practiced with different disability groups.

4. With the virtual reality application, pedestrian skills can be studied by creating conditions involving drivers with different seasons, lights, and driving profiles.

5. In addition, similar studies in which social validity data are collected can be carried out with participants, families, and teachers.

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Ethics statement: In this study, we declare that the rules stated in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with and that we do not take any of the actions based on "Actions Against Scientific Research and Publication Ethics". At the same time, we declare that there is no conflict of interest between the authors, that all authors contribute to the study, and that all the responsibility belongs to the article authors in case of all ethical violations.

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Data Availability Statement: Data generated or analyzed during this study are available from the authors on request.

Conflict of Interest: There is no conflict of interest between the authors and the author.

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