User Experience Observations on Factors That Affect Performance in a Road-Crossing Training Application for Children Using the CAVE

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Abstract. Each year thousands of pedestrian get killed in road accidents and millions are non-fatally injured. Many of these involve children and occur when crossing at or between intersections. It is more difficult for children to understand, assess and predict risky situations, especially in settings that they don't have that much experience in, such as in a city. Virtual Reality has been used to simulate situations that are too dangerous to practice in real life and has proven to be advantageous when used in training, aiming at improving skills. This paper presents a road-crossing application that simulates a pedestrian crossing found in a city setting. Children have to evaluate all given pieces of information (traffic lights, cars crossing, etc.) and then try to safely cross the road in a virtual environment. A VR CAVE is used to immerse children in the city scene. User experience observations were made so as to identify the factors that seem to affect children's performance. Results indicate that the application was well received as a learning tool and that gender; immersion and traffic noise seem to affect children's performance.

Keywords: CAVE, User Experience, Road Crossing, Children, and Training.

1 Introduction

Each year thousands of pedestrians lose their lives in road accidents and millions are non-fatally injured. Many of these are children and occur in accidents when crossing at or between intersections, primarily when children are going to and from school. It is more difficult for young children to understand, assess and predict risky situations, because of poorly developed perceptual and attention abilities especially in settings where they don't have that much experience, such as in a busy city.

Many governments have realized the great importance of road safety education and have developed well-organized initiatives towards increasing awareness and training, especially among young children. Early practical experience is acknowledged by all as the most important factor to improve road safety skills among children. Studies have shown [1] that increasing knowledge does not necessarily improve behavior. Investing on getting practical experience seems to be the key to alleviate this problem.

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Current strategies used to train children in safe pedestrian behavior include group education, individualized roadside behavioral training; computer based training and virtual reality training. Virtual reality represents the newest approach and has several advantages: children can engage in potentially risky situations, such as road-crossing, without facing any risk, they can practice without time restrictions, the settings can be adapted according to the child's individual needs (which might include disabilities) and last but not least VR applications are highly engaging.

In the study presented in this paper, we try to study the effectiveness of a specialized VR CAVE application as a learning tool to improve 9-year old children's road-crossing skills. Furthermore, by observing and monitoring children's experience/ behavior we try to identify factors that seem to contribute to successful road-crossing performance in the VR CAVE. The results of this study are discussed, as well as the next steps towards this research direction.

2 Background

Children's road crossing skills and their behaviour in traffic may be influenced by a variety of factors including demographics and individual differences, cognitive ability, as well as visual, attention and perceptual skills. Much of the literature suggests that young children are less competent in traffic than older children and adults because of poorly developed perceptual and attention abilities, which consequently increases their risk as pedestrians [2], [3], [4]. A more recent study [5] that involved children aged 6 to 11, concluded that younger children took longer to make correct decisions with respect to road crossing and also seemed to be affected negatively by auditory and visual distractions. Keeping the above in mind, it is recommended that children be supervised when crossing roads until they reach the age of nine.

Virtual Reality allows one to do more than just imitate reality. If that was the only goal, then it may be simpler to manufacture physical props with which a participant could practice some procedure. What virtual reality adds is the ability to practice uncommon, expensive and dangerous tasks. Additionally, the operator has more control over what scenarios can be presented to the participant, and can change the scenario in response to performance. The other significant benefit is that performance can be recorded and analyzed.

The effectiveness of virtual reality has been tested in a pedestrian-safety training situations for children since 2002 [6]. Thomson et al. [7] conducted a study with 7, 9 and 11-year old children, looking at their road-crossing judgments before and after training with a computer-simulated traffic environment. Trained children performed better, crossing more quickly, missing fewer opportunities to cross safely and generally demonstrating a better understanding of the factors considered when making crossing decisions. Schwebel et al [8] conducted an important study confirming the validity of human behavior in the virtual world matching the same person's behavior in the real world using an immersive, interactive virtual pedestrian environment.

3 VR CAVE Application for Road-Crossing

3.1 Software and Equipment Used

For the design and development of the immersive application in the VR CAVE environment we used the EON Studio Professional for the implementation, Autodesk Maya and 3ds Max for the 3D modeling and animation production. A road-crossing learning environment was developed. In this environment, there is a crossing, with the crossing button, lights and cars that commute in a street of a city. The child has the opportunity to navigate and interact with the virtual world. The child can press the button at the crossing, wait until cars stop and lights change from red to green and then cross the street.

Fig. 1. VR CAVE, glasses, Xbox controller

The EON REALITY iCube VR CAVE was used to display the 3D virtual environment which was viewed using a pair of active stereo shutter glasses. Interaction and navigation were performed using an Xbox game controller. Both the stereo glasses and the Xbox controller were tracked using a non-invasive infrared position tracker. The former allowed the view of the environment to be updated according to user head movements.

The VR Cave consists of four screens (to the front, left and right of the viewer and one on the floor). Each screen is displayed by one of four HD projectors. The participant stands between the screens and with the help of the active stereo glasses is immersed in the 3D world being displayed (see Figure 2).

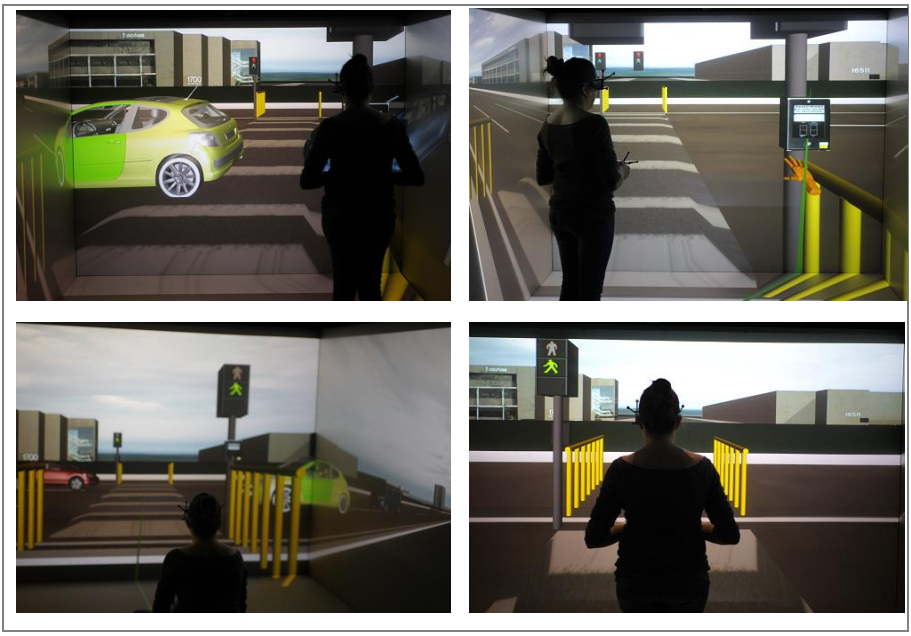

Fig. 2. Screenshots from VR CAVE application for road crossing

3.2 The Study

The goal of this research was to design and develop an immersive application in a VR CAVE environment for improving children's road-crossing skills, as well as to study the factors that influence performance.

A city is an environment that it is realistically dangerous for young children especially because of cars, but indirectly because of heavy noise levels and continuous distractions which can disturb concentration. They have to learn how to cross the road safely, identify and avoid cars, recognize and press the crossing button and recognize and interpret traffic signs and lights. Specifically, in the scenario used for this study, the following learning processes are involved:

- The child recognizes, tracks and avoids moving cars within the virtual street scene
- The child recognizes and finds the crossing button, walks to it, stops, and presses it
- The child recognizes the traffic lights and how to interpret them (red light means stop and green means walk)
- The child recognizes the crossing and walks over it, if it is safe to – based on the lights and cars

In this study the main objective was to investigate which factors seem to affect children in their behavior in road-crossing using the VR CAVE environment. Traffic noise was added to study its influence on road-crossing behaviour. It is commonly believed that background noise can affect concentration and can increase stress levels

[9]. Additionally, questions involved finding out whether the children felt immersed, whether the application can be used for educating children to learn how to cross a road safely, the devices were easily used by children and also if it offered an enjoyable experience.

Eleven children (9-10 years old) participated in the study. The evaluation was empirical and was assessed by a pre-test questionnaire, by making observations during the session, and by a post-test questionnaire. Four girls and seven boys between 9 and 10 years old were selected randomly among sixty children of a primary school that had come to the research lab for a visit, as part of an educational excursion. Consent forms were signed by parents/guardians, informing them about the particular study and giving details about their children's participation.

The procedure for each session was as follows. First of all, the child was asked to wear shoes and glasses, which are necessary in order to enter the VR CAVE environment. After that, it was explained to the child how to use the Xbox controller in order to interact and navigate within the environment. For 5-10 minutes, we gave the opportunity to the children to play with the Xbox controller in order to familiarize themselves with it and learn how to handle it and interact with the environment.

The session for each child consisted of four trials: two with traffic noise and two without (with no specific order). The steps that each child was expected to execute during each trial in order to complete the session successfully, were the following:

- Press the button at the crossing box (the child did this by pressing a button on the Xbox controller)
- Look right and left in order to check if cars are coming
- Wait until cars stop
- If the cars stop and the pedestrian lights are green, then cross the road
- Cross the road and get to the other side safely

Participants filled a pre-test questionnaire and a post-test questionnaire. Also, during the session the observers kept a form for each child to record observations. The pre-test questionnaire contained questions related to the child's skills with technology, and electronic gaming habits (e.g. hours per week). It also included questions relating to their subjective level of knowledge of road-crossing, as well as some questions concerning attention and how easily they get distracted. The observation form and the post-test questionnaire focused on specific proposed judgment categories, such as mistakes made, difficult points in interaction, etc.

3.3 Data Analysis

Most children reported in the pre-test questionnaire that they already knew how to cross the street; one child stated that they knew a little, and another one that they knew but never before had the chance to cross a road alone. All children owned one or more electronic devices: PC, tablet and smartphone. They reported using their electronic device for browsing the Web (91%), for playing games (91%), for doing homework (45%), for Social Networking (45%). Most children (64%) reported

playing electronic games for less than 5 hours per week, while the rest (36%) said they played for 5-20 hours per week. There were three attention related questions in which children were asked (a) whether their attention gets distracted (e.g. from noise, conversations, etc.), (b) how difficult do they find it to concentrate on a telephone conversation when their favourite TV program starts and (c) how often do they find themselves repeating pieces of text when they are reading. Answers were distributed somewhat evenly when seen for all participants, but a tendency was observed in boys being more easily distracted when reading text, whereas girls had more difficulty concentrating in a telephone conversation (**Error! Reference source not found.**).

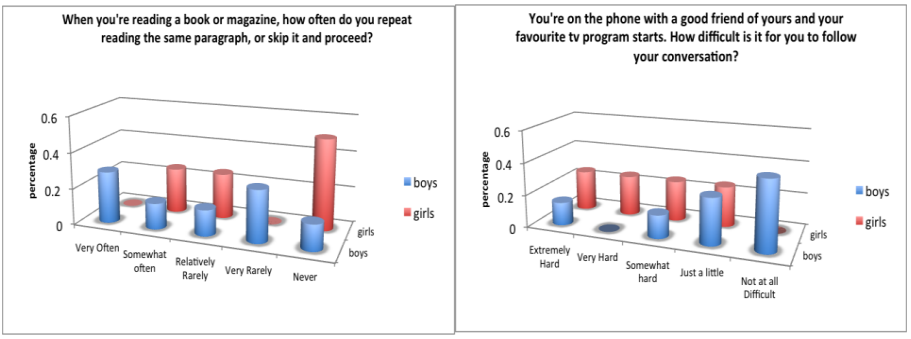

Fig. 3. Boys and Girls responses to attention-related questions

Almost all children verbally mentioned and demonstrated through gestures and facial expressions that they greatly enjoyed the virtual street-crossing experience. The post-test questionnaire results indicated exactly the same. Additionally, only 27.27% of children mentioned that they felt dizziness during their experience, while 64% of the children answered that they got immersed. 91% answered that they felt the whole experience and interaction was compatible with the real world and all of them agreed that the application would be an excellent learning tool. Regarding the adequacy of the application we measured if children found the use of the equipment (hand controller/ glasses/ shoes) restrictive. 55% of children reported founding it restrictive, referring primarily to the glasses being uncomfortable due to them being relatively large and perhaps too heavy for children of their age.

After careful analysis of the data, we observed that boys outperformed girls in all aspects in the four trials. Figure 4 summarizes these findings. Boys did significantly better when it came to waiting for the green light before crossing, look left and right and generally in successfully crossing the road.

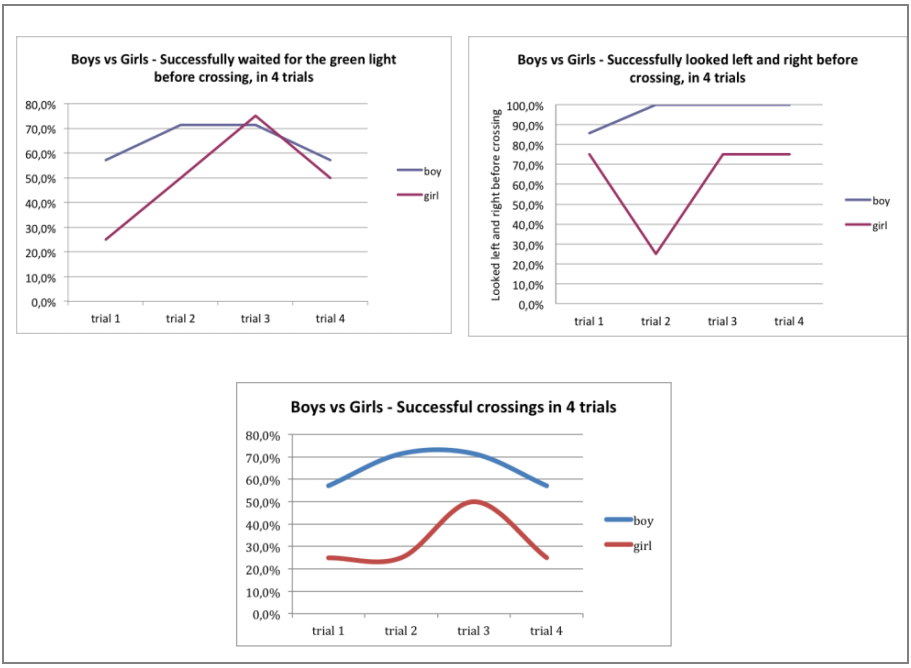

Fig. 4. How Gender Seems to Affect Performance

Another factor that seemed to affect children's performance was their sense of immersion. Children who reported that they felt immersed when interacting with the application did significantly better than those who said they did not (**Error! Reference source not found.**).

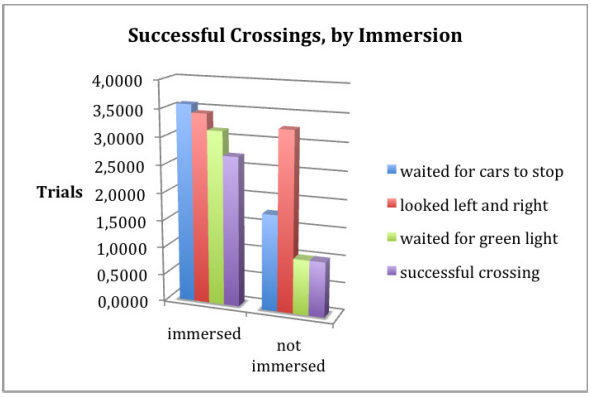

Fig. 5. Successful Crossings by Children who reported being immersed and not

Children who reported feeling that their knowledge on how to successfully cross a road improved after their experience with the VR CAVE application, also demonstrated better performance compared to children who felt their knowledge did not improve (**Error! Reference source not found.**).

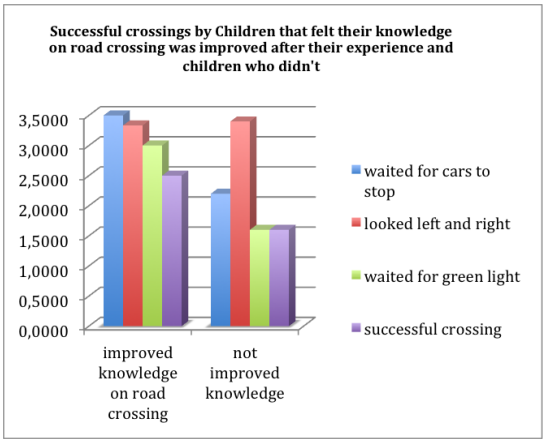

Fig. 6. Successful Crossings by Children who reported improved knowledge on road crossing after their experience and children who did not

Finally, the influence of bakcground noise was studied, offering each subject two trials with traffic noise and two trials without. The starting state was alternated for each subject: so some experienced with-noise in the first trial and others without-noise. Across subjects, noise did not seem to affect performance as such. However, it was observed that subjects who started with a "without noise" trial performed better in all trials compared with subjects who started with a "with noise" trial (**Error! Reference source not found.**).

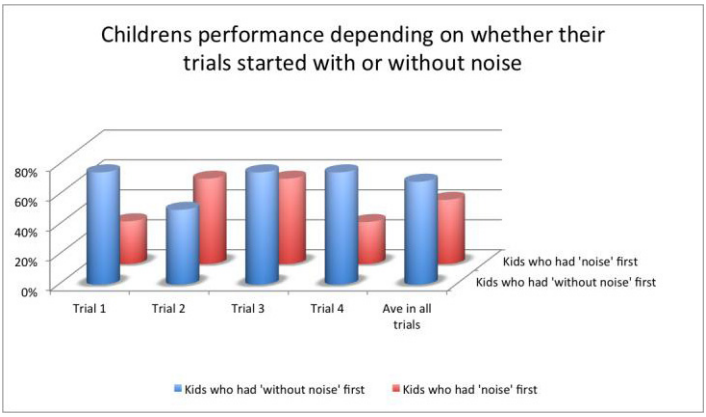

Fig. 7. Children's Performance depending on whether their trials started with or without noise

No particular relation was found between children's responses to attention-related questions and their performance. In Table 1, we report on children's responses to question "Your attention is easily distracted (by e.g. noise, people talking around you, etc.) with possible responses "Yes", "Sometimes" or "Never" and their performance in the four (4) trials, based on successful crossings.

Table 1. Performance observations, by subjective attention level

Question: You are easily distracted (e.g. by noise, by others' conversations, etc.)		To_wait	lookleftright	waitgreenlight	Cross_ok
yes	Mean	3.0000	3.2000	2.2000	1.6000
	Std. Deviation	.70711	1.30384	1.64317	1.81659
sometimes	Mean	3.5000	4.0000	3.0000	3.0000
	Std. Deviation	.70711	0.00000	1.41421	1.41421
never	Mean	2.5000	3.2500	2.2500	2.2500
	Std. Deviation	1.91485	.95743	1.70783	1.70783

4 Conclusion

The results indicate first of all that the VR CAVE application for road-crossing training of children can be beneficial as a learning tool. The children who participated in the study (9 year olds) all interacted with the virtual environment smoothly and had no difficulties handling any of the devices. All of them reported to have had a pleasurable experience and most of them felt that they improved their knowledge on safe road crossing. However, a more accurate tool for assessing learning effectiveness would be needed in future studies.

Questionnaire results in combination with user performance observations (waiting for cars to stop, looking left-right, waiting for the green light and successfully crossing) revealed that boys out performed girls in all aspects and that children who reported feeling immersed in the VR CAVE application did much better as well. Indeed gender, as a factor influencing the sense of presence and realness, has been investigated in recent studies [10] reaching similar conclusions: male subjects feel more present than female subjects in virtual environments.

In addition it was noticed that children who felt their knowledge improved after interacting with the application, also did better. Attention-related questions were included in the pre-test questionnaire, but data was not sufficient to draw conclusions that can relate attention levels with performance. In addition, children's responses about their own attention abilities might be seen as not objective enough to draw firm conclusions relating attention to road-crossing ability. A more specialized attention related test would need to be administered to get more conclusive results.

Finally, we were not in a position to draw important conclusions concerning traffic noise, which was added as a distractor in two out of four of the trials, however it was

noticed that children who got “no traffic noise” trials first performed better than those who got the opposite. This possibly indicates that traffic noise distracted children at the beginning of their session and affected their overall performance.

Despite the fact that this initial study’s population was not very significant so as to safely generalize the results, they are nevertheless promising results and a follow-up, larger scale study is therefore justified.

5 Future Work

A larger scale study is in the immediate future plans. More children have to experience the CAVE application to extract results that can be generalizable. It is believed that factors such as traffic noise (or other distractors) and attention levels might appear to actually have an important influence on successful crossing. Investigating the impact, differences and corresponding factors that influence performance when children have a disability, such as autism, is also being planned.

We have concluded that the VR CAVE environment can be used as an educational tool in road safety with promising results. The application appeared to have contributed to the improvement of children’s knowledge about safe road crossing, but a more accurate assessment tool will need to be devised. One of the factors affecting performance, such as immersion, indicates that we need to invest resources on improving the users sense of immersion.

Next steps also involve broadening the collection of scenes of the application, including more road-safety situations one can encounter in a city, such as cyclists, traffic lights that are not working, basic road signs, etc.

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References

1. Zeedyk, M.S., Wallace, L., Carcary, B., Jones, K., Larter, K.: Children and road safety: Increasing knowledge does not improve behaviour. British Journal of Educational Psychology 71, 573–594 (2001)
2. Connelly, M., Conaglen, H., Parsonson, B., Isler, R.: Child pedestrian’s crossing gap thresholds. Accident Analysis and Prevention 30(4), 443–453 (1998)
3. Dunbar, G., Hill, R., Lewis, V.: Children’s attentional skills and road behaviour. Journal of Experimental Psychology: Applied 7(3), 227–234 (2001)

4. Whitebread, D., Neilson, K.: The contribution of visual search strategies to the development of pedestrian skills by 4-11 year-old children. British Journal of Educational Psychology 70, 539–557 (2000)
5. Tabibi, Z., Pfeffer, K.: Finding a safe place to cross the road: the effect of distractors and the role of attention in children's identification of safe and dangerous road-crossing sites. Inf. Child Develop. 16, 193–206 (2007)
6. McComas, J., MacKay, M., Picik, J.: Effectiveness of virtual reality for teaching pedestrian safety. Cyber Psychology & Behavior 5(3), 185–190 (2002)
7. Thomson, J.A., Tolmie, A.K., Foot, H.C., Whelan, K.M., Sarvary, P., Morrison, S.: Influence of Virtual Reality Training on the Roadside Crossing Judgments of Child Pedestrians. Journal of Experimental Psychology: Applied 11(3), 175–186 (2005)
8. Schwebel, D.C., Gaines, J., Severson, J.: Validation of virtual reality as a tool to understand and prevent child pedestrian injury. Accident Analysis and Prevention 40, 1394–1400 (2008)
9. Andrews, M.A.W.: How does background noise affect our concentration? Scientific American (January/ February 2010), http://www.scientificamerican.com/article.cfm?id=ask-the-brains-background-noise
10. Felnhofer, A., Kothgassner, O.D., Beutl, L., Hlavacs, H., Kryspin-Exner, I.: Is virtual reality made for men only? Exploring gender differences in the sense of presence. In: Proceedings of the International Society on Presence Research, pp. 103–112 (2012)