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Technical report:

The Dome simulator validation

Validation of the Semi-immersive dome shaped pedestrians' virtual reality simulator

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Abstract

The simulator validation study confirms the simulator's ability to correctly simulate the real road environment, and strengthens the reliability as a source for statistical Inference. The goal of this work was to investigate whether the Dome simulator successfully simulates typical pedestrian environment in a manner that will elicit people to act in the same manner as they would in the real world crossing situations. Data analysis shows that the simulator delivers more reliable results concerning speeds rather than distances. Questionnaires analyses show that the simulator's faith to reality regarding the display, sound effect and perspective is medium.

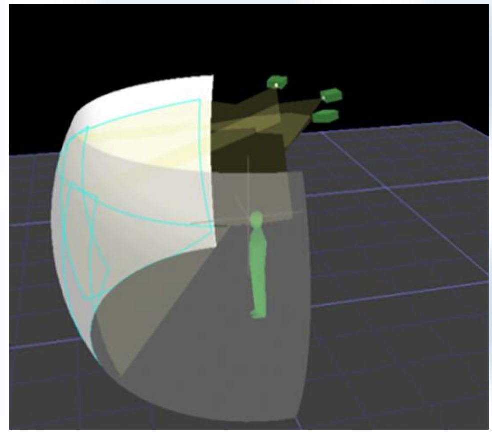

Figure 1. Dome projection facility at BGU Ergonomics complex

The Dome

The Dome simulator consists of 180 degrees spherical screen (radius of 3.25 meters) aligned with a very accurate projection system of three projectors. This array allows a simultaneous projection from three different sources to be tailored into a single wide angle 3 dimensional view (see Figure 1). The facility is both temperature and noise controlled. The dome projection system integrates the natural visual and motor skills of an operator into the system he or she is controlling. It is large enough to have participants and their workstation immersed within its circumference. In addition, physical movement can be added to enhance strain and to improve simulation fidelity. This setting allows measurement of the participants when watching pre-designed simulated scenarios of real-life situations from the roadside perspective, without the risk of harm. The dome facility is equipped with an advanced 5.1 channels sound surround system that enables an immersive experience. Crossing simulated scenarios are built using VT-MAK simulation applications in a three dimensional generic model of a typical local city, ensuring that participants will be able to relate to environmental road and urban features and recognize them (Figure 2). The scene includes typical urban environmental features, such as: street signs, bus stops, benches, garbage cans, vegetation, etc.

Method

30 students aged 20-30 participated in a within subjects experiment of three stages.

First phase: “real-world” physical validation

We took typical “compact” car to a side road in the BGU university complex and asked the participants to stand on the curb and evaluate the distance of the car (while in halt) in five different ranges (10, 30, 50, 60 and 80 meters, not in that order). Next, we drove the car in three different speeds (10, 25 and 40 kilometers per hour, not in that order) and asked the participants to evaluate the driving speed. Research assistant stood by the participants on the curb and instructed them and wrote down their responds. Participants were also requested to evaluate the distance to the other side of the road, hence, the road wide from one curb to the other.

Second phase: “real-world” behavioral validation

At this phase participants were placed on a curb facing one-way two-lane road looking at the approaching traffic. All participant were brought to the same pre-determined location. The participant held a flag and was instructed to raise the flag when he feels it is safe to cross the road, after ordered by the research assistant to start. Each participant performed 10 crossing trials. Video camera was placed in a position to record the pedestrian and the approaching traffic. Time gap and distance from the closest vehicle approaching at the "crossing point" was calculated from the data extracted from the video recordings, utilizing auxiliary means placed in the fixed distances along the road.

Third phase: simulator validation

After completing the first two phases at the "real-world", participants arrived at the Dome simulator facility and after a short familiarization with the simulated world they viewed the simulated scenarios. First they viewed 5 motionless scenarios and ask to estimate the distance from a standing vehicle, in 5 different distances (corresponding to the distances presented in the physical validation). After, they were asked to estimate the driving speed of a single traveling vehicle at 3 scenarios each time in different speed (corresponding to the driving speeds presented in the physical validation). After this part they viewed 10 dynamic scenarios each minute long (corresponding to the behavioral validation). Each scenario featured two-lane one-way road with a traveling traffic in a similar density, variance and speed as in the "real-world" crossing location (as measured earlier). The instructions for the participants were to press a designated button when they feel it is safe to cross the virtual road. It was explained to them that pressing the button symbolized the initiating of the road crossing in a steady walking pace.

Fourth phase: subjective evaluation of the simulator through questionnaires

After completing the simulator session participants were asked to fill a subjective feelings questionnaire. The questionnaire included seven questions formulated by us to estimate the participant feelings based on his subjective experience regarding the simulator ability to accurately reflect reality.

Figure 2. Typical view from the simulated virtual-reality 3d city including moving traffic.

Figure 3. Participant standing in the center of the Dome viewing a simulated scene.

Results

Physical validation

Table 1. Averages of the perceived distances

Evaluation place\Distance (meters)	10	30	50	60	85
The Dome (simulator)	7.8	23.1	41.5	55.6	75.9
Road side (Real-world)	10.8	35.9	46.7	61.2	75

Table 2. Averages of the perceived speeds

Evaluation place\Speed (km/h)	10	25	40
The Dome (simulator)	15.1	29	43.3
Road side (Real-world)	12.6	27	33.4

Behavioral validation

Table 3. Average distance from the approaching vehicle and time to vehicle arrival, as it was at the crossing decision

Evaluation place	Distance (meters)	Time to arrival (seconds)	Pulse rate (bpm)
The Dome (simulator)	88.1	8.2	84.6
Road side (Real-world)	68.4	7.8	80.7

Subjective questionnaire

Table 4. Average of participants' subjective evaluation of the simulation ability to simulate reality in several measures

Measure\simulate level	Not at all	Relatively simulates	Highly simulates
Reality	0	22	8
Sound effects	0	16	14
Objects	0	17	13
Viewing angle	2	17	11
Display quality	1	20	9

Table 5. Average of participations' subjective of their safety and ease of making the crossing decision

Evaluation place\Distance	Simulator	Real-world	No difference (in both unsafe)*	In both safe
Safety feeling*	11	6	2	11
Ease of decision making	7	15	8	

Discussion of the results and conclusions

Performing statistical T-test ($p<0.05$) found that the Dome simulator gives a good fit to speed (10, 25 km/h) and distance perception (10, 50, 60, 85 meters) to speed and distance perception in the real-world. Although speed perception matched the actual speed, still it was somewhat estimated as higher in the simulator than the perceived speed in the real-world. Hence, in real-life participants tended to underestimate the driving speed of the vehicle more than in the dome simulator. Findings showed a good fit in short range (up to 10 meters), long ranges (over 50 meters) and certain deviation in others. Still, it seems that distance was somewhat underestimated in the simulator in compare to the perceived distance in reality. Findings also showed a good fit in the participant aability to estimate the road wide in the simulator and in the real-world. The statistical tests also showed participants made a similar crossing decision in term of time to arrival, which mean the time for the next car to arrive at the crossing path after making the crossing decision. In both conditions participants used similar minimal time gaps for the crossing, this is very valuable since the purpose of the simulator is to stimulate similar crossing behavior, as it does.