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INVESTIGATING THE USE OF VIRTUAL REALITY FOR PEDESTRIAN ENVIRONMENTS

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Simulated virtual environments have been used as a testing tool in various disciplines. In planning, transportation planners have extensively used simulated environments to test drivers' perceptions, training, and adaptability. However, these simulators have not been used to test pedestrian environments, owing to the lack of research on the adaptability of virtual simulators for walking-oriented research. This study investigates the ability of individuals to use the driving simulator for pedestrian research by modifying the simulated pedestrian environment and testing the individual's ability to identify the variations in the built environment. The result of this study indicates that the participants were able to identify the variations in the built environment in the driving simulator; thus, the driving simulator can be adapted for pedestrian research. Future advancements in technology can help improve the test scenarios and assist urban planners, transportation planners, and health professionals in conducting pedestrian research in a controlled setting.

INTRODUCTION

Virtual reality (VR) has been used as an investigational tool in various applications, such as psychological therapy (North, *et al*., 2002; Rizzo, *et al*., 1998; Waller, *et al*., 2004), surgical training (Tendick, *et al*., 2000), military exercises, and flight simulation. In transportation planning, VR has been used to identify landmarks and drivers' perceptions of the built environment and for work-zone analysis (Bella, 2005; Mitchell, *et al*., 2005). VR has also been used by researchers to test the behavior of individuals in a virtual environment (VE) to aid decision making in the real-world environment (Clark and Daigle, 1997; Lockwood, 1997; see also Reffat, 2008; Yan and Kalay, 2004). VEs have been validated and extensively used by transportation researchers because they do not result in physical injury to the participants during experimentation (Simpson, *et al*., 2003).

However, to date most of the transportation-related studies that use VR have investigated driving experiences in the simulated environment, while fewer studies have examined walking experiences using virtual simulation. It is important to conduct an investigation of the pedestrian experience of street corridors because the experience of individuals while driving differs from that of walking the same street corridor. Therefore, this study investigates the extent to which parents identify and spatially relate to the features of the simulated pedestrian environment around schools. Their experience of walking through the pedestrian VE was evaluated by their ability to detect variations in the simulated features of the built environment and to spatially identify their proximity to those features across six test scenarios in the VE.

The following section illustrates the development and use of VE in transportation research and research related to an individual's ability to locate one's self with respect to the simulated features of the VE. The following section also describes the experimental setup, participant characteristics, and method of analysis. Finally, the results of the analysis are discussed, and conclusions are given along with recommendations and the implications of this study.

BACKGROUND

Jansen-Osmann (2002) classified VR systems into two primary display systems: desktop display systems and immersive display systems. Desktop display systems project the VR experimental setup onto a computer screen, whereas the immersive display system gives the participants a chance to interact and be completely immersed in the experimental setup. Other suggested display systems include intermediate display systems, such as the use of projected screens and three-dimensional monitors. Although these systems immerse the participants in the experimental setup, the participants may or may not actively interact with the simulated environment.

Transportation research has used each of these display systems in the course of investigating an individual's responses to the simulated environment. Desktop display systems have been extensively used in transportation planning to test the egocentric spatial updating capabilities of participants. "Egocentric spatial updating," as defined by Waller (2005) and investigated by Klatzky, *et al.* (1998) and Wang (2000), is the mental ability of the participants to track the changing relationship between themselves and external objects as they move through the VE. Other studies that used similar techniques were conducted by Demetre and Gaffin (1994), Demetre, *et al*. (1992, 1993), and Lee, *et al*. (1984), who incorporated actual traffic into their study.

While these studies investigated the spatial abilities of the participants, other studies have used desktop display systems to investigate participant responses to the simulated built environment. Loomis, *et al.* (1999) conducted spatial studies to understand the relation between people's performance and built environments of varying geographic scales. Researchers have created built environments ranging from small-scale environments, such as buildings, to large-scale environments, such as campuses and cities (McNamara, *et al.*, 2003; Montello and Pick, 1993; Sholl, 1987), in controlled experiments to investigate the factors that affect mental representations of environments. Another study (Waller, 2005) investigated the ability of participants to relate to an occluded landmark. However, Waller recommended the use of an interactive experimental setup that required the use of a participant's body motion during the experiment.

Simpson, *et al*. (2003) used the immersive display system to investigate the road-crossing abilities of children and young adults to factor in the impact of speed, traffic flow, and distance between vehicles in a realistic experimental setup. They tested the extent to which pedestrians of different ages and sexes relied on information concerning varying speed and inter-vehicular distance in crossing roads. This study overcame the limitations of previous studies by employing the head-mounted display technique, which increased the realism of the simulated environment and engaged participants without causing any physical danger. Other immersive display systems, such as driving simulators, have been used to test the variables in road conditions (Kraan, *et al*., 1999), drivers' perceptions (Hustad and Dudek, 1999), driver assessment and training response (Cook, *et al*., 2004), and various other factors that lead to accidents and driving hazards. Immersive simulators have helped researchers develop and test scenarios, such as fatality as a result of the effects of weather conditions on speed and driving (Rama, 1999), without physically harming the participants. One of the main reasons that immersive display systems have gained popularity among researchers is because these VEs have the ability to engross the subjects' attention, submerging them into the simulated environment and stimulating them to respond to the test scenarios. A study conducted by Lockwood (1997) inquired about the participants' response to the realism of the simulator. Thirteen out of 15 participants reported the simulator was at least adequately realistic. Similarly, in a validation study conducted by the University of Florida (Klee, *et al*., 1999), drivers behaved in the same way in 10 of the 16 designated locations along the road in the simulated and real-world environments.

The third display system amalgamates the techniques of both the desktop display system and the immersive display system. This technique is particularly useful when the investigations require individuals to respond to the test scenarios by observing the simulated environment without actively engaging in the experiment. The present study uses this intermediate immersive display technique to test the participant's response to the simulated pedestrian environment. This study particularly investigates whether the participants identify the variations in the proximity and features of the simulated built environment. It uses the GlobalSim driving simulation authoring tool, which inherits the advantages of the immersive VE by using the hyperdrive simulator. This PC-based software package provides an easy-to-use interface to design, build, execute, and analyze scenarios to study the interaction between human behavior and the built environment.

METHOD

This study precedes a larger study that investigates the impediments perceived by parents that would prevent them from letting their children walk to school (Kweon, *et al*., 2004). Parents of schoolchildren from the twin cities of College Station and Bryan, Texas, were invited to participate in this study. The focus group interviews were analyzed based on the frequency of themes identified through the use of the QSR "NUD·IST" program (see Appendix). For example, lack of trees was mentioned throughout the interviews. The main purpose of wanting trees was to provide shade and improve the scenic quality of walking (*e.g.*, participants stated, "[W]hen they've got shading and other things around it, it's a little cooler to walk than the general sidewalk is, where you have the road, you have the sidewalk but you have no tree" [Mom 2]; "Well, trees may not be safer, but they will give shade" [Mom 6]). However, no one mentioned the trees as a vertical buffer between the street and the sidewalk. Based on the constructs of the built environment indicated by the parents during the focus group meetings, six controlled test environments were developed in the simulator.

Twenty-six parents with at least one child enrolled in an elementary school in the twin cities volunteered to participate in this experiment. Their ages ranged from 25-48, with a mean of 36.1 years. Seventy-three percent of the volunteers were women. Eighty percent of the volunteers had at least a college degree and a mean income ranging from $40,000-$60,000.

Development of Test Scenarios

Content analysis of the transcribed recordings of the parent focus groups indicated various environmental constructs that parents perceived as barriers to letting their child walk to school. These constructs were matched against the capabilities of the simulator to develop or manipulate them in the VE (Table 1). Features such as the roads, sidewalk, and ground surface are typically available in various combinations of tiles (or templates that cannot be manipulated in the simulator). Features such as trees, houses, and signals can be introduced when and where desired on these tiles, based on the researcher's design requirement. The three

TABLE 1. Availability of identified physical constructs in the hyperdrive simulator.

	Total	I/NI/NA	Availability in simulator	Static/dynamic elements
Sidewalks (generally tiled)				
Width	23	I	Available	Static
Lack	23	I	Available	Static
Sharing with bike	13	NI	Available	Dynamic
Maintenance	10	NA	NA	NA
Street (generally tiled)				
Pedestrian crossing	33	NI	Available	Static
Signals	23	NI	Available	Static
Curbs and ramps	17	NI	Available	Tiled
Street lights	6	NI	Available	Tiled/dynamic
Width	6	NI	Available	Tiled
Intersections	3	NI	Available	Tiled
Traffic				
Speed	18	I	Available	Dynamic
Volume	16	I	Available	Dynamic
Landscape buffer	10	I	Available	Tiled
Trees	10	I	Available	Static
Off-road paths	29	NI	Available	Tiled
Weather	14	NI	Limited availability	Scripted

Notes. Total = Frequency of discussion; I = Introduced; NI = Not introduced; NA = Not available in the simulator.

main constructs of the built environment that influenced the parents' perceptions of safety (and that were capable of being simulated) were sidewalks, buffers, and trees.

For the purpose of this study, experimental scenarios were developed to test the effects of (1) the availability of sidewalks, (2) buffers of varying widths, and (3) the introduction of trees to the walking environment. Other built environment constructs were dropped from the analysis because either they were not available on the simulator or they were believed to affect the analysis of the three test variables in the experiment. For example, an intersection, by itself, is a complex built environment variable that is impacted by the availability of signals, crosswalks, and ramps, as well as the width of the road. Also, the experience of walking on an off-road path, as shown by various research studies, is different from the walking environment on the sidewalks along the transportation corridor. Weather was not incorporated into the study because the simulator had limited ability to reflect the variable.

For the simulated scenario, ambient traffic with maximum density was selected to resemble the environment around schools during peak hours. Dynamic traffic and pedestrians were introduced to simulate the morning school hours with maximum average daily traffic. Buffers were introduced as elements in the tiles on the pedestrian walkways. Since the sidewalks and buffers were tiled, testing of the pedestrian walkways for various maintenance works was not incorporated into the study. Trees were tested for their effect on the walking experience.

To design the experimental setting according to the three constructs, schools in the cities of College Station and Bryan were evaluated in terms of the present condition of the sidewalk, the setback from the sidewalk, the spacing of driveways, the setback from the street, the width of the tree lawn (grass strip from the end of the curb to the start of the sidewalk), the spacing of trees, and other physical conditions that could be represented in the simulated world (Figure 1). These were then drafted in AutoCAD. The three constructs identified were manipulated to create the six test scenarios to be used for this study (Table 2). Standards and references, such as road manuals and the American Association of State Highway and Transportation Officials' (AASHTO) road standards, and other design references, such as *Accommodating the Pedestrian* by Richard Untermann (1984) and *The Community Builders Handbook* (Community Builders Council, 2000), were used to draft these six test scenarios. These were then used to develop the simulated test scenarios in the virtual simulator (Figures 2-3).

Test Procedure and Inquiry

Each participant viewed the six randomly ordered test scenarios and answered the questionnaire after the completion of each scenario. The participants viewed each simulated scenario for one and a half minutes and

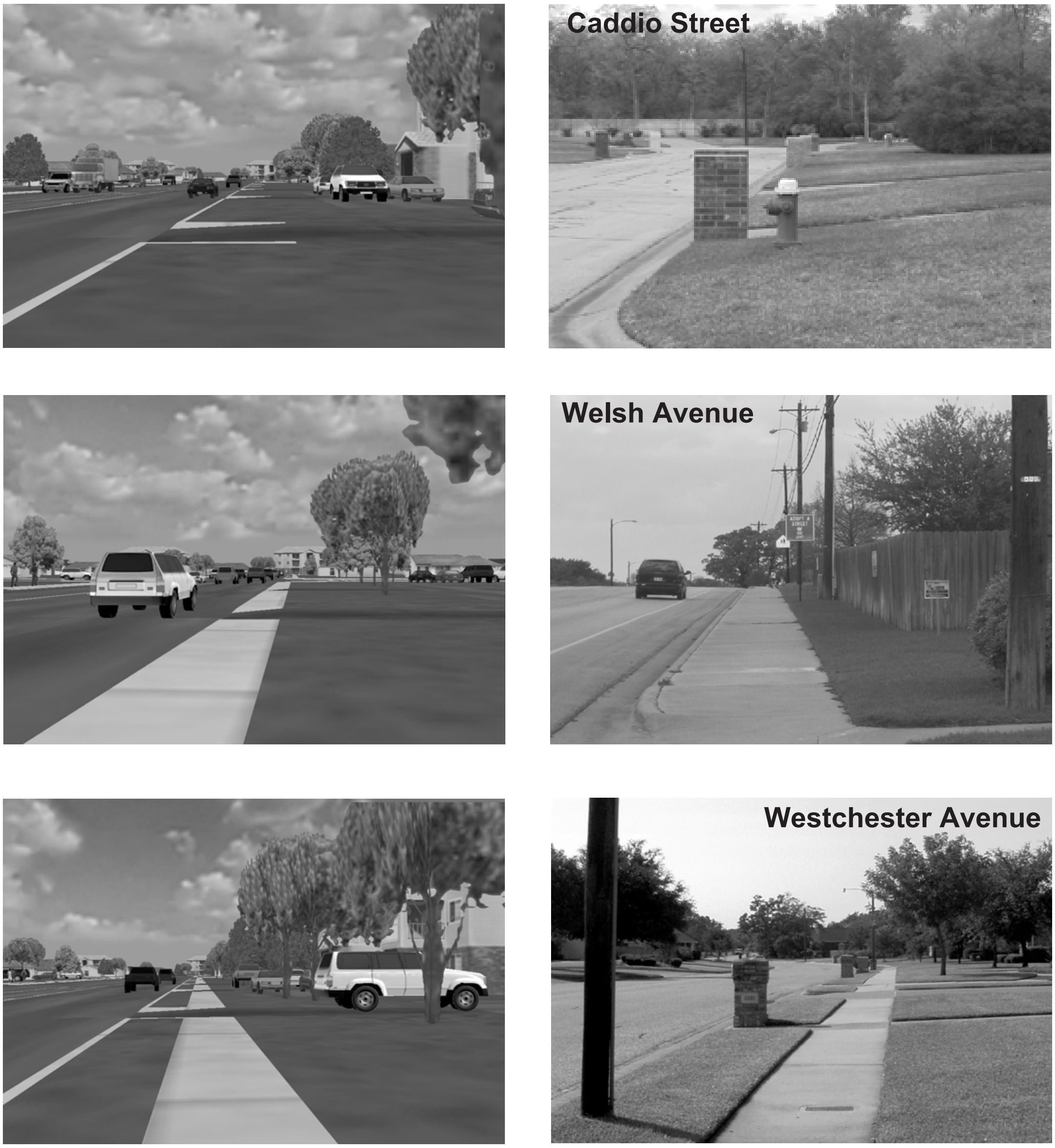

FIGURE 1. Sample of simulated sidewalk environments and study area for Scenarios 1-3. Condition 1 (top): No sidewalk and no buffer between walking area and traffic. Condition 2 (middle): Sidewalk without buffer between walking area and traffic. Condition 3 (bottom): Sidewalk with narrow buffer.

were given time to complete the survey. The questionnaires inquired about the physical constructs of the built environment, such as the amount of lawn, the width of the sidewalk, the amount of parking, etc., for each of the test scenarios after the participants "walked" (*i.e.*, viewed the walking environment) through each test environment. The participants ranked the environment based on a three-point scale to gauge the simulated test conditions for the quantity of built environment features (1 = too much; 2 = just enough; 3 = too little) or proximity (1 = too close; 2 = just right; 3 = too far). For example, based on the amount of traffic, the participants reported each test scenario as either too much or too close, based on their proximity to the traffic.

Sixteen survey questions, 11 measuring the quantity of built environment features and five measuring the proximity to these features, were answered by 26 participants for each of the six scenarios. The observations of one participant were not used, since the responses of said participant did not adhere to the response scales on the questionnaire and were therefore dropped from further analysis. This resulted in a total of 25 participants across six scenarios, leading to a total of 150 responses for each of the 16 questions. Multiple

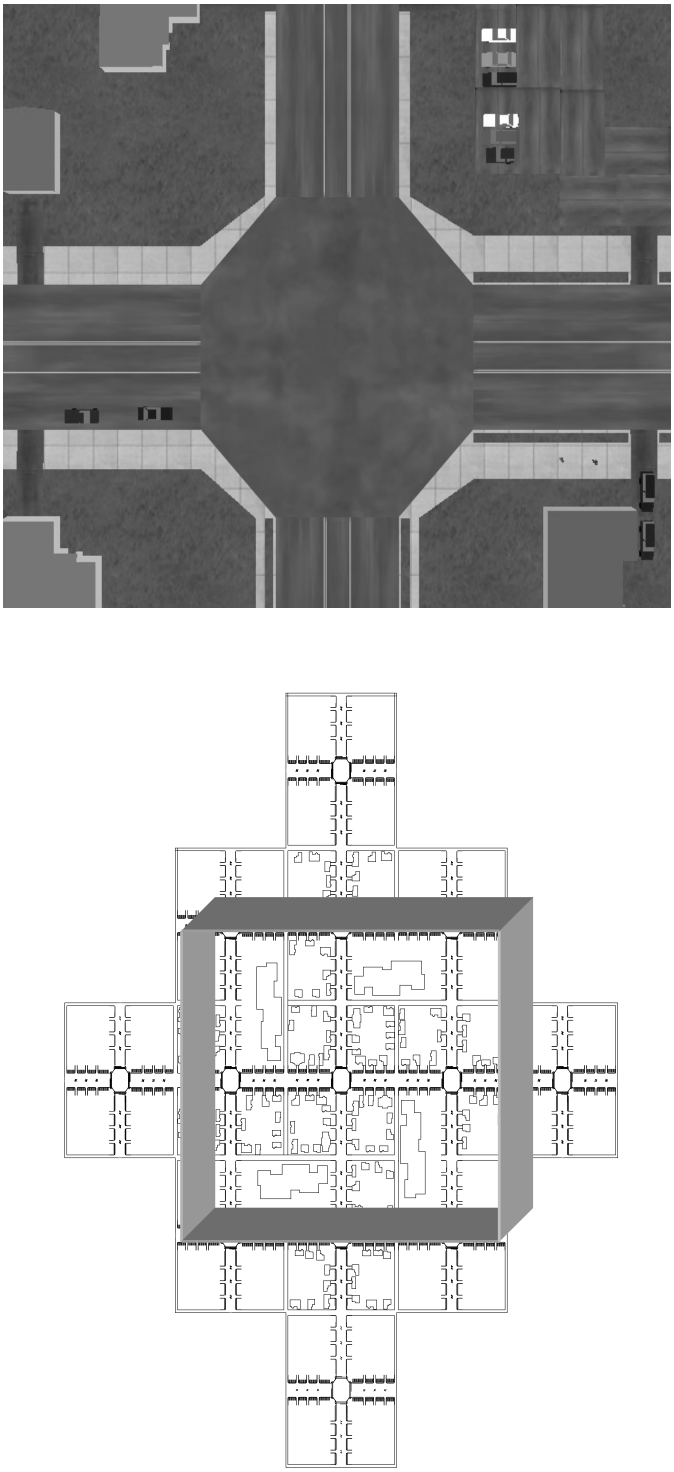

FIGURE 2. Actual (top) and drafted (bottom) tile setup in the hyperdrive simulator.

analysis of variance (MANOVA) was performed to check if the responses of the participants and the Eta scores varied across the six test scenarios. This would help identify if the participants were able to identify the variations incorporated across each test scenario and if they were able to check their visual location based on the simulated environment. The expected outcome of this analysis was that individuals would be able to identify the built environment features that vary across the test scenarios, versus those that did not vary significantly in the virtual simulator. For example, proximity to trees varied with each test condition, whereas proximity to housing did not. If the simulation was valid, respondents should be able to identify these variations effectively.

EVALUATION OF THE SIMULATED ENVIRONMENT

Average values indicated that parents generally perceived too much traffic, proximity (too close) to traffic, and proximity (too close) to the road across the test scenarios (values on the three-point scale were typically below 1.5 for each scenario; see Table 2). The presence of parked cars, number of driveways, amount of parking, proximity to houses, and proximity to parking ranged from around 1.5 to 2 (2 = just enough or just right). The amount of overall greenery, lawn, tree canopy, and tree trunks and the width of the sidewalk were generally ranked from too little to just right as the scenarios varied from no sidewalk (Scenario 1) to sidewalk and wide buffer (Scenario 6). The mean proximity to trees ranged between just right and too close in Scenario 5 (1.90) and Scenario 6 (1.82) (both narrow and wide sidewalk with trees), compared to other scenarios.

The results of the MANOVA revealed a strong difference among the six scenarios as viewed by the respondents. While the purpose of univariate tests, such as ANOVA, is to detect statistical differences among the characteristics of a single variable across groups, the multivariate counterpart, MANOVA, detects statistical differences among the characteristics of the composite variable across groups. The composite, or latent, variable in this case is the scenario that is the composite of variables such as overall greenery, lawn, etc. Therefore, MANOVA was used to test if the six test scenarios were different from each other. The data

TABLE 2. Means for different test scenarios in the simulator.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Buffer	No	No	4'	8'	4'	8'
Sidewalk	No	Yes	Yes	Yes	Yes	Yes
Street trees	No	No	No	No	Yes	Yes
No variation — amount of features						
Presence of parked cars	1.43	1.68	1.57	1.54	1.75	1.56
Number of driveways	1.56	1.59	1.52	1.59	1.55	1.60
Level of maintenance	2.04	2.00	2.04	1.95	1.90	2.00
Amount of parking	1.47	1.81	1.85	1.90	1.75	1.69
Variation						
Amount of overall greenery	2.13	2.00	1.95	2.27	1.90	1.86
Amount of lawn	2.34	2.00	1.38	1.90	1.90	2.08
Sense of enclosure	2.52	2.09	2.61	2.36	2.10	2.04
Amount of tree canopy	2.00	2.36	2.23	2.31	2.10	1.82
Number of tree trunks	2.13	2.09	2.47	2.40	1.95	1.82
Amount of traffic	1.30	1.59	1.23	1.45	1.50	1.21
Width of sidewalk	2.39	2.31	2.80	2.27	2.20	2.43
No variation — proximity to features						
Proximity to parking	1.52	1.72	1.57	1.63	1.55	1.47
Proximity to houses	1.82	1.54	1.95	1.63	1.70	1.69
Variation						
Proximity to traffic	1.13	1.40	1.00	1.68	1.60	1.39
Proximity to trees	1.91	2.22	2.50	2.40	1.90	1.82
Proximity to road	1.13	1.50	1.04	1.68	1.65	1.43

Notes. 3 = too little or too far; 2 = just enough or just right; 1 = too much or too close.

reported statistically significant differences (Wilks' lambda = 24, $F(5,80)$ = 2.305, $p < 0.001$, partial Eta-squared = 24.8) for all the variables, as identified by the respondents (Table 3). The result shows that each test scenario, as a composite of the variables, was perceived to be different from the other test scenarios. This, in itself, indicates the success of the simulator as a valid instrument for simulating environments. This also shows that each environment has a unique characteristic that can be identified through the values of its parameters (the variables and the amount of variables used).

FIGURE 3. An aerial snapshot of the test world created for this study.

Although the univariate results of multivariate tests are not generally interpreted, the effect sizes for the univariate results were interpreted to identify the features of the built environment that were more easily recognized by the respondents in the simulated test conditions. To keep the integrity of the MANOVA intact and avoid inflation of the Type I error rate, only the effect sizes (Eta scores) of the univariate results were interpreted. Variations in the environmental features, such as lawns, tree trunks, sidewalks, enclosures, and variations in proximity to traffic, trees, and roads, reported partial Eta-squared values ranging from 10 to 24.3. The variables with higher effect sizes contributed more toward multivariate statistical significance. Table 3 lists these variables and their corresponding effect sizes.

The patterns of responses for the variables with larger effect sizes are presented in Figure 4, which shows the means of the variables for each scenario. These plots revealed that the three features of the built environment and the three proximity variables reported as visually identifiable variations across scenarios.

TABLE 3. Results of MANOVA analyzing the relationship of scenarios to simulated features and proximity to simulated features.

MANOVA	Value	df	*F*	*p*	Eta scores
Condition — Wilks' lambda	0.240	80	2.305	< 0.001	0.248
Between subjects					
No variation					
Parked cars		5	0.814	0.542	0.032
Driveway		5	0.044	0.999	0.002
Maintenance		5	0.398	0.849	0.016
Parking		5	1.388	0.233	0.053
Variation					
Greenery		5	1.892	0.100	0.070
Lawn*		5	7.319	< 0.001	0.226
Enclosure*		5	3.422	0.006	0.120
Tree canopy		5	2.250	0.053	0.083
Tree trunk*		5	5.270	< 0.001	0.174
Traffic		5	1.856	0.107	0.069
Sidewalk*		5	3.951	0.002	0.136
No variation					
Parking		5	0.565	0.726	0.022
Houses		5	1.401	0.228	0.053
Variation					
Traffic*		5	6.889	< 0.001	0.216
Tree*		5	8.044	< 0.001	0.243
Road*		5	6.707	< 0.001	0.212

*Statistically significant at 0.05 level.

Although enclosure had a comparatively higher effect size, the means for the scenarios did not vary much across the six test scenarios.

DISCUSSION

The variations in the features of the built VE, as perceived by the parents of schoolchildren, were distinctly identified, and spatial cognizance within the simulated pedestrian environment was tested. The environmental features that varied within the VE were identified across six test scenarios, and other physical features within the VE that did not vary were not statistically significant. Therefore, individuals were able to identify and relate to the variations that occurred across the six pedestrian VEs, suggesting that the simulation of a built environment can be effective for walking-related studies.

In this study, the simulations of available built environment elements were ranked by the participants from too much or too close (1) to too little or too far (3). The descriptive analysis of the observations showed that the amount of traffic was too much, while the proximity to traffic and the road was too close. It was the researchers' intention to introduce high curbside average daily traffic to resemble the morning traffic near schools. This ranking indicates that the participants comprehended the simulated environment as intended by the researchers in this study. Also, the change in ranking the amount of lawn and tree canopy and the width of the sidewalk from too little in Scenario 1 to just right in Scenario 6 was in response to the introduction of a sidewalk in Scenario 2, the introduction of buffers in Scenarios 3 and 4, and the introduction of trees in Scenarios 5 and 6. With the introduction of trees in Scenarios 5 and 6, the participants felt the proximity of the trees to be too close. Also, the level of maintenance was ranked just right by the majority of the participants because the tiles designed for this experiment did not include damaged pavement or any type of physical hindrance, such as garbage cans on the sidewalk.

The virtual simulation of pedestrian environments in the driving simulator was effective for individuals to identify specific variations across the six test scenarios. The features of the built environment that were modified across the test scenarios were the only ones identified to be statistically different, in comparison to the other features that remained the same across the test scenarios. The modifications in the test scenarios were the outcome of the variations in the amount of sidewalk, trees, lawns, and enclosure. Proximity to the built environment features in the simulator revealed that proximity to road, traffic, and trees varied across the test scenarios. The results of this study indicate that the introduction of a sidewalk affected proximity to the road,

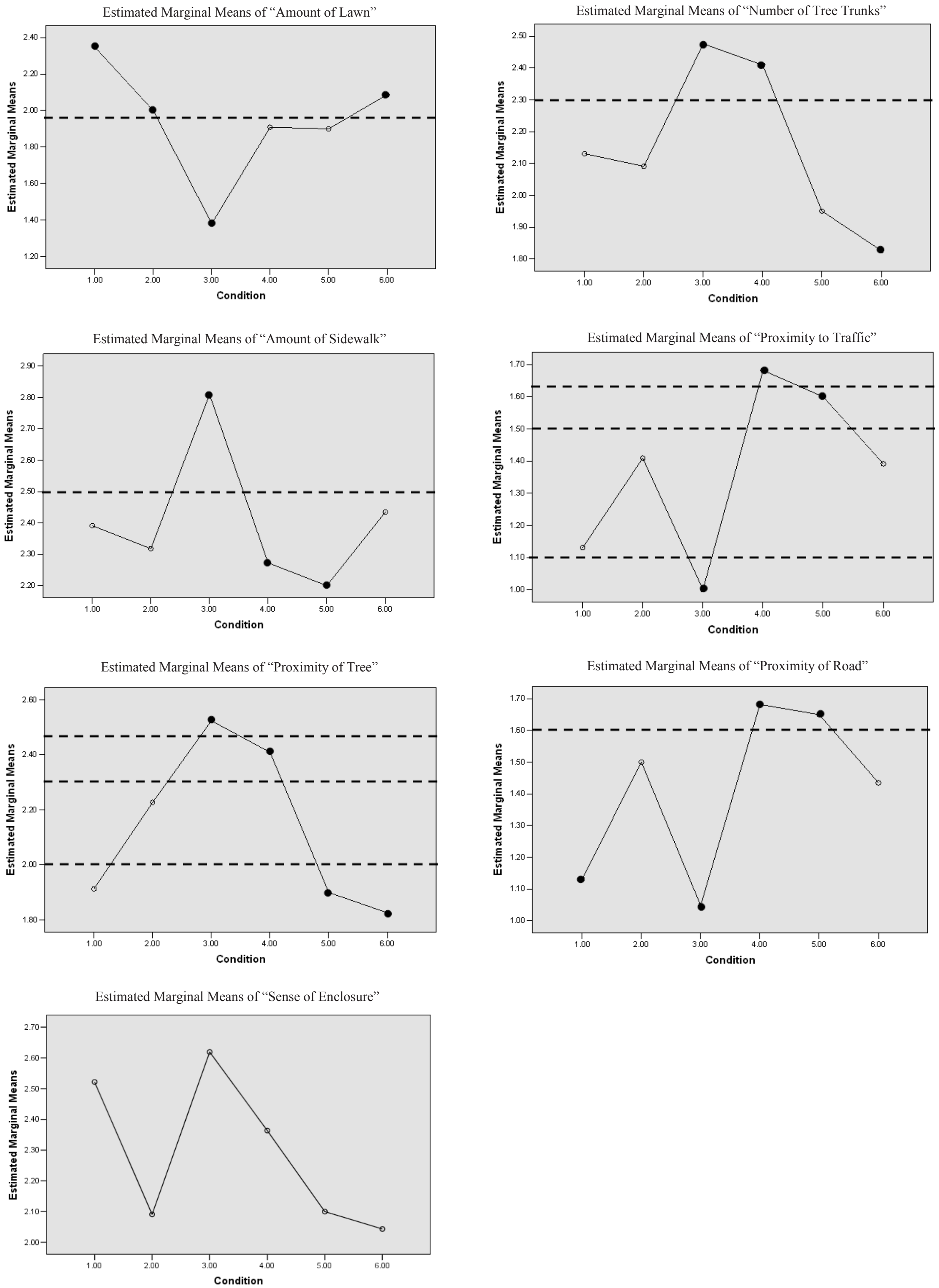

FIGURE 4. Plots of means for variables with higher effect sizes across the six scenarios.

the introduction of lawns affected proximity to traffic, and the introduction of trees on the lawns affected the responses with respect to proximity to trees. Based on the outcome of this study, it can be concluded that the driving simulator can be effectively used for pedestrian-oriented research in a controlled setting.

CONCLUSION

The present study provides evidence that the participants in the experimental setup are able to evaluate the built environment measures of the pedestrian setup in the simulator usually used for driving tests. Although participants were informally asked about the reality of their experience in the simulator, they were not formally assessed. Generally, the participants reported the simulation to be comfortable and realistic during the debriefing discussion. However, they also reported that the simulations jerked due to change in ground level from driveway to the sidewalk. The simulator was limited in providing other cues important to the gestalt of the pedestrian perception, including neurological impacts of motion, smell, sound, and other sentient content. This weakness could be overcome with further investment in the simulation capacity of artificial intelligence and computer technology.

Thus, the use of the simulator for pedestrian-oriented research can be viewed as a valuable resource for testing experiments, such as pedestrian-vehicle accidents, in a safe way, which cannot be done in a real-world situation. However, comparison between the simulation and the real-world environment needs to be conducted to better validate the use of simulators for pedestrian-oriented research. Preliminary validation of the simulated environment conducted by Klee, *et al*. (1999) investigated the driving speed, distance, and time of individuals in identical real-world and simulated driving environments and found similar behavior at designated locations along the road. Similar studies could be conducted to validate the VE using a pedestrian environment setup. Kaptein, *et al*. (1996) reported that the presence of movement and a higher image resolution can increase the validity of simulated environments. Additionally, this study used a semi-immersive simulation method where the participants were made to view the simulated environment. Future studies can use a better-calibrated interface, such as a joystick or even a treadmill, to enable the participants to walk through the environment as they desire. However, analysis using that interface could lead to spurious results if the participants do not have enough training and practice on the use of those interfaces. For instance, if the participants have not had a chance to practice using a joystick to walk through the environment, they could be inclined to divert their attention to managing their movement through the environment, rather than observing the environment.

The present study avoided such deviation through the use of simulated scenarios without the subject being influenced by the interface. This study was able to test the egocentric spatial updating abilities of the participants with respect to the changing features of the built environment and the participants' proximity to those features in the VE. This will help transportation planners, urban planners, landscape architects, and health professionals make inquiries in a controlled environment and informed decisions on interventions to encourage walking in communities around the nation.

APPENDIX: TRANSCRIPTION OF BARRIERS AND OPPORTUNITIES DISCUSSED BY THE PARENT FOCUS GROUP

Barrier to walking	Opportunities for improvement
Inability to negotiate curves with training wheels	Addition of signals at intersection
Unsafe crosswalk because cars rarely stop to yield	Addition of more crosswalks to reduce vehicular speed
Too far to walk	Addition of stop signs
Heavy traffic	Addition of walk sign
Hwy. 6 crossing is not possible	----
Unsafe for child to walk on her own because of traffic conflicts	Addition of pedestrian ramps
Road (Greens Prairie from Wellborn) is not wide enough to accommodate bike or walking infrastructure	Addition of walkway separated from the street by a tree lawn
Distance from school	Consider sight lines to mid-block pedestrian crossings in traffic design
Necessity of crossing numerous intersections	Addition of four-way stops

APPENDIX continued. Transcription of barriers and opportunities discussed by the parent focus group.

Barrier to walking	Opportunities for improvement
Availability of a bike lane	Addition of bike lanes separate from road
Necessity of jumping curbs when using the sidewalk as a bike lane	Addition of curb-cuts for sidewalks
Necessity of getting on and off bike to use the infrastructure	Create visible bike lane connections to improve speed and access
Private property preventing direct access from origin to destination, especially at cul-de-sac adjoining park	Make it more efficient for pedestrians (walking and biking)
Not fast enough, takes too long, or is too indirect	Make it convenient (make walking a faster and better choice than driving)
Kids on bicycles use sidewalk and make it dangerous for walkers	Change limitation on school zone distances so that it includes major crossings for pedestrian network
Landscape alongside sidewalk prevents bicyclists from negotiating past strollers that are occupying the full width of the sidewalk	Need to accommodate two strollers side by side and still have room for bicyclists to pass
Too much foot traffic for bicyclists to use sidewalk	Install extended school zone designation
Cars don’t respect bike lanes and use them as part of car lane	Put bike lane at different height
Sharing space or lane with car	Addition of pedestrian cross light
Length of route may require parent to accompany child for protection along route	Locate route for pedestrians to minimize driveway conflicts (one side of street may be better than another because of land-use adjacency)
Visibility along whole length of route would be needed	Need visibility along off-road paths
Litter on the road pushed off to the side	Beautiful big trees for shade
Right turn allowed at red lights combined with left turners at T-intersection	Making pedestrian/bike lane completely separate from car lanes would be ideal
Kid falls into road if biking on road	Addition of parks and speed bumps, as well as limiting car speed to 10 mph and less car access
(No) company to walk to school with	Separate lane from street through elevating the path for kids with tree lawn
----	Rolled curbs
----	Addition of bike racks at destinations to ensure safety of parking bikes
Designated traffic lanes	Addition of places for bikes to pass without going into road
Lack of supportive land use (single family home?) along route	Put stripes on paths to regulate
Access to neighborly help	----
If there were places for kids to go, then more would go, and they would watch out for each other	Bee Creek is nice because it is wide, has stripes on paths, and is fun
Total lack of infrastructure support	Creation of walkway through shortest route and away from road and traffic, like the handicap ramp for bicycle access across intersections, as curbs can be difficult to navigate
Lack of time to destination	Planning of route from residential area to school
Traffic route	Signage needs to be more prominent and visible from long distance
Sidewalk bumpy and not easy to traverse	Natural environment, like parks and trees, available at comfortable distances

APPENDIX continued. Transcription of barriers and opportunities discussed by the parent focus group.

Barrier to walking	Opportunities for improvement
Walk sign not associated with traffic light	Addition of dotted line on sidewalk for walkway and pedestrians
----	Addition of high street with connecting streets (planning)

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