# Modeling the Real World using STISIM Drive® Simulation Software: A Study Contrasting High and Low Locality Simulations.

Craig K. Allison, Katie J. Parnell, James W. H. Brown, & Neville A. Stanton

Faculty of Engineering and the Environment, University of Southampton, Boldrewood Innovation Campus, Southampton, SO16 7QF, United Kingdom
{Craig.Allison, kp4g13, J.W.Brown, N.Stanton}@soton.ac.uk

**Abstract.** This paper presents work undertaken to develop a high locality simulation of a real world driving environment within the STISIM Drive® v3 software. The paper considers the tools and techniques used to develop the simulation model and then examines the impact that the addition of realistic models has on driver performance metrics. In order to test the developed simulation model, participants drove both a high and low locality version of the same route in a driving simulator as well as the real world route. Drivers' levels of immersion, perception of presence, performance metrics and subjective workload ratings were considered. Results from an initial pilot study suggest that individual differences play a role in participants' levels of presence between simulations. Results are discussed in terms of potential future research.

**Keywords:** Human Factors · Simulation · Tool Development · STISIM

## 1 Introduction

Driving simulators have facilitated research into a range of driving behaviors within Human Factors research, including responses to automated driving [1], the potential distractive effect of in-vehicle technologies [2] and the environmental impact of different driving behaviors on fuel economy [3]. Simulators allow naturalistic behaviors to be studied under high levels of control as well as enabling the manipulation of variables found in the real world, within a low risk and safe environment. This is useful within the driving domain where on-road studies are associated with large ethical concerns regarding the drivers, as well as other road users, safety. Yet, the utility of driving simulators is dependent on their ability to accurately replicate real-world conditions. Often, the simplicity of simulation models used within a simulator setting mean results cannot be reliably applied to the real world without further testing. Shechtman, Classen, Awadzi, and Mann (2009, p. 380) [4] vocalized the concern that work is needed to support the use of driving simulators in order to accurately reflect real world environments and situations by suggesting that "driving simulators must be validated before they are used for driving assessment and/or training."

One popular piece of driving simulation software used for research purposes is STISIM Drive® v3 (STISIM). STISIM facilitates the recording of a variety of driving metrics as well as allowing freedom in scenario development. This program has been used to explore a variety of different driving related influences and tasks including the effect of alcohol on driving performance [5], the distractive effects of in-vehicle technology [6], and even the effects of chewing gum whilst engaged in the driving task [7].

As mobile beings, humans possess a spatial reference system, allowing them to place objects within a spatial array [8] and understand their surroundings. One influential theory accounting for how individual understand their surroundings is the Landmark-Route-Survey model [9]. This suggests that individuals learn about salient visual items within their environment, the routes that link these salient landmarks, before finally developing an ornithological or "birds eye view" understanding of the environment. As landmark cues are salient markers within a route, presenting these cues within a simulated environment should allow an individual to place their current position within a known spatial context. By placing an individual within a simulation of a known environment, populated by known salient landmarks, it would be expected that participants driving would more accurately match the real world, and that participants would experience a greater level of involvement within the environment, referred to in the literature as higher levels of presence [10].

Salient localized features do not come as standard within typical simulation tools such as STISIM. It would be incredibly difficult to create a package that could be customizable to possess local route features to suit all users needs. Therefore, within most simulator research that has utilized this tool, local features are absent. Yet, it is suggested here that the inclusion of local landmark cues within simulation models may influence the driver's levels of presence. To explore the effect of local landmark cues, a simulation model of a real roadway environment was developed using STISIM. Central to the development of the simulation environment was the creation of a custom library of models, used to supplement the default set available within STISIM. Three open source programs were used to create the models, Inkscape, GIMP and Blender, with the completed models subsequently imported into STISIM. The development of the custom objects included capturing adequate textures and images of the real environment and applying appropriate scaling to ensure their accurate representation within the simulation model.

To assess whether the inclusion of custom objects influenced participants driving metrics and subjective experience during the simulation, two simulations were developed, a high locality simulation, which included the developed custom landmark objects, and a low locality simulation, which only used objects available in the standard STISIM library. In addition, participants were invited to drive the real world route in order to examine whether presence within the simulation differed from their presence on road. To summarize, this paper aims to explore the effects of local landmark cues on drivers subjective level of presence and speed, both with simulations and compared to on road driving.

## 2 Experimental Method

### 2.1 Participants

Seven participants, (4 Male, Mean age= 28.5 years and 3 Female, Mean age = 32.3 years) were recruited. Participants were required to be over the age of 25 and hold a valid UK driving license with no more than 3 points on their license. Participation was voluntary and the study lasted approximately 1.5 hours. As the study was looking to explore the effect of local landmark cues it was important that all participants were familiar with the area that was being constructed within the simulation (Southampton and the surrounding area). Therefore, participants were recruited that lived or worked in Southampton and frequently (2 times a week or more) drove the roads included in the route. Ethical approval was granted from the University of Southampton research ethics committee (Ergo ID:25422). Informed consent was obtained from each participant prior to the start of the study.

### 2.2 Equipment

*University vehicle:* For the on-road condition participants drove the University of Southampton TRG SRIF2 instrumented vehicle. This was a right-hand drive Fiat Stilo with an automatic transmission.
*Driving Simulator:* In the two conditions that required the participants to drive simulated routes, the Southampton University Driving Simulator (SUDS) was used. This is comprised of a fixed base right-hand drive Land Rover Discovery, with an automatic transmission. STISIM M500W wide-field-of-view system was used to create the simulated environment. Three screens positioned in front of the vehicle captured the forward projection of the road scene with 135-degree field of view. A single screen at the rear of the vehicle shows the projected rear-view image that can be seen in the vehicle's rear-view mirror.


**Fig. 1.** The university vehicle used for real world driving and the SUDS driving simulator, University of Southampton.

### 2.3 Questionnaires

In order to test the level of presence felt by participants the "Presence Questionnaire" [11] was presented following each trial. In addition, participants were required to complete the NASA-TLX to measure subjective workload. In order to gain an understanding of the underlying characteristics of the participant to feel immersed in virtual environments, participants' completed the Immersive Tendencies Questionnaire [10].

### 2.4 Procedure

All participants completed a demographics questionnaire at the start of the experiment. A map of the route participants were asked to drive was then presented (Figure 2.). The route was 13.2 miles long, taking approximately 30 minutes to drive. The route contained a variety of different road types including motorways (Highways), residential roads, rural roads and urban roads The order participants completed the three experimental conditions (On-road (OR), low-Locality simulation (LL), and high-locality simulation (HL)) was counterbalanced to limit potential order effects. Participants completed a 5-minute training drive in the driving simulator before completing the simulator trials to familiarize themselves with driving in a simulator. They were also encouraged to drive the instrumented vehicle around the car park before they began the on-road trial to acquaint themselves with the vehicle and its capabilities. For all conditions, a member of the research team sat in the passenger seat and asked the participant to drive the constructed route, providing directions where necessary. At the end of each trial, participants completed both the presence questionnaire and NASA-TLX before progressing to the next trial. Once participants had completed all three trials, they completed the immersion questionnaire. Figure 3. presents the same scene from the real world, and both low and high locality simulation environments.

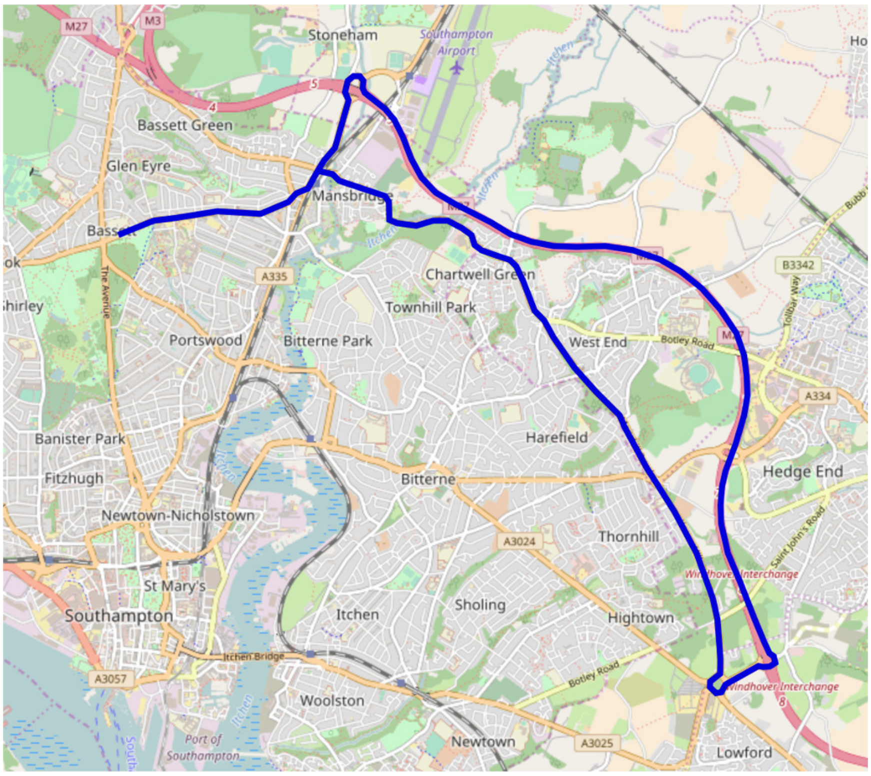


**Fig. 2.** The route participants were asked to drive within the study. Map produced using OpenStreetMap.

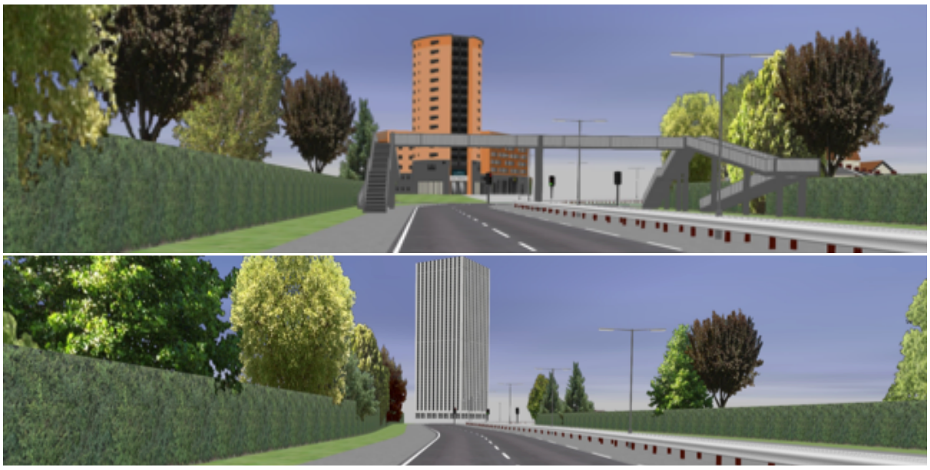

**Fig. 3.** A scene from the real world, and both high locality and low locality simulations.

## 3 Results and Discussion

As the data reported within this paper examines responses from an initial pilot study of seven participants, no inferential statistics tests have been calculated. Rather, the results are discussed in terms of current trends within the data, highlighting areas which require additional attention and data to be collected. The use of pilot studies to trial simulator studies is well known [4], and has been used within this simulation software to good effect before [12].

### 3.1 Immersion and Presence

Figure 4. presents participants' level of immersion as percentages. It can be seen from the graphs that large individual differences are apparent in immersion scores. This is apparent when examining participants "Play/Gaming" scores, although no participants reported themselves as particularly high in "Play/Gaming", participant 5 did score very low in this metric. Participants also reported themselves as relatively high in "Focus" with the exception of Participant 6.

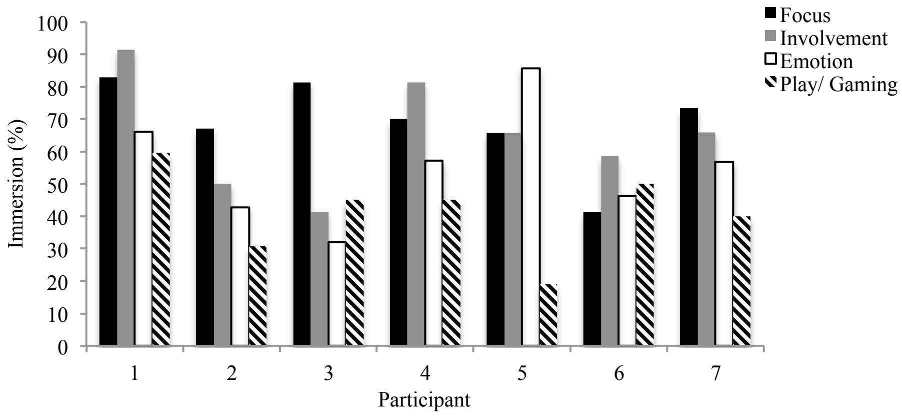


**Fig. 4.** Participants level of self reported immersion.

Figure 5. presents recorded presence scores for each participant, by trial type. For all participants it can be seen that presence was rated highest in the on road trial, an expected outcome, however mixed results can be observed when examining the simulation environments. This initial finding suggests that increased detail and local features does not guarantee an increase in recorded presence for all participants. However, there appears to be a link between presence within the simulations and reported levels of "Play/ Gaming". Participants who reported low "Play/ Gaming", for example participant 5, reported greater presence within the low locality simulation. In contrast, participant 1, who recorded the highest level of "Play/ Gaming" expressed significantly greater presence within the high locality simulation. Further work is warranted to examine the interplay of these two variables.

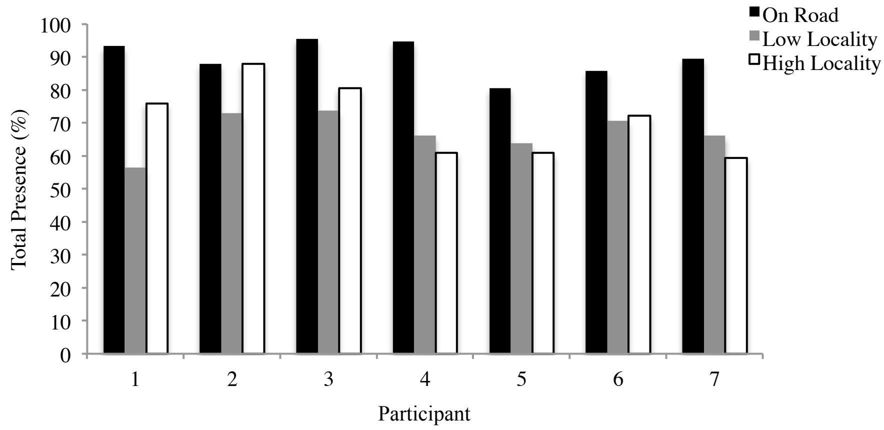


**Fig. 5.** Participants self-reported presence across the three conditions.

### 3.2 Workload

Figure 6. presents the mean self reported workload scores for each NASA-TLX sub-scale. It can be seen that participants recorded lowest workload when driving on

road. Whilst workload is typically higher in the low locality version of the simulation, participants experienced considerably greater mental demand in the high locality simulation. The root cause of the increase in this sub-component is however currently unknown, and may be a consequence of the high salience of the custom objects present within this trial. Due to the increased graphical complexity of these objects, participants attention may have been artificially drawn to these objects, increasing the relative demand of the driving task. Future research utilizing eye-tracking technology is required to confirm this explanation.

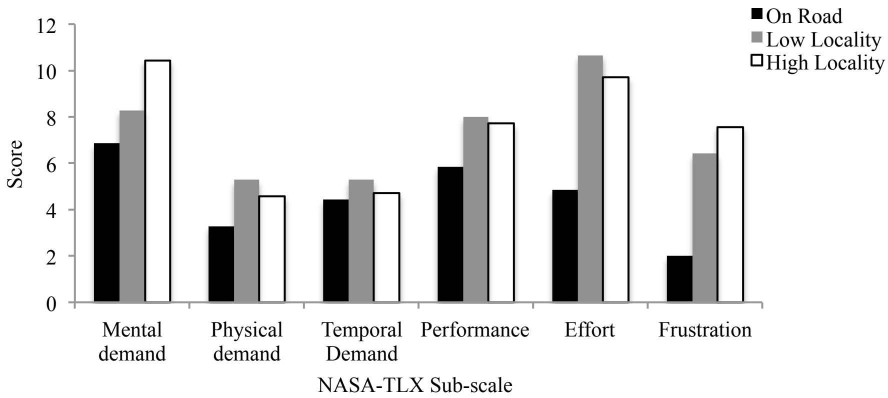


**Fig. 6.** Participants self reported workload, based upon NASA-TLX scores.

### 3.3 Speed Profiles

Figure 7. presents the mean speed profiles recorded within the simulation environment. It appears from Figure 7. that participants drove at generally lower speeds within the high locality simulation than the low locality simulation.

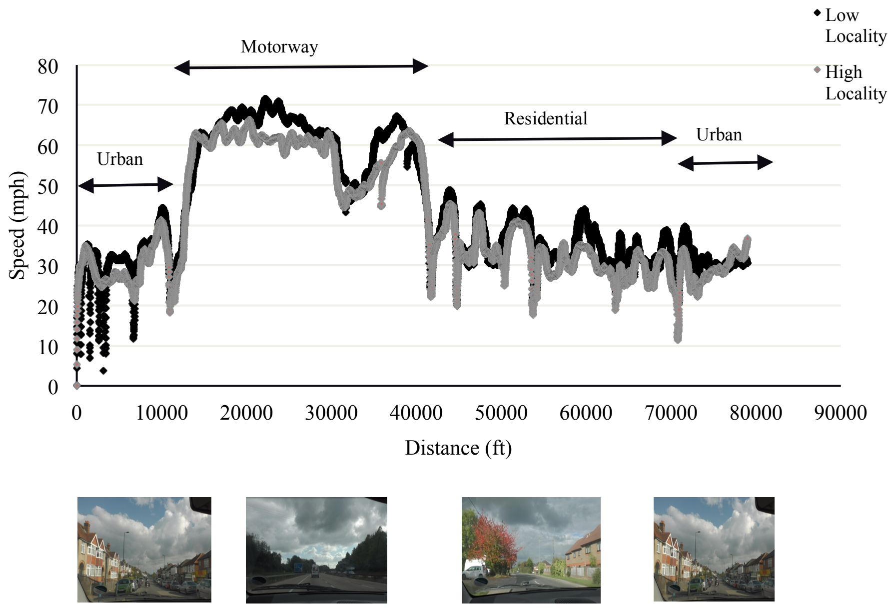


**Fig. 7.** Speed profiles recorded with both low and high locality simulation trials.

Several explanations can be posited to suggest why participants speed varied as a consequence of the simulation locality. It is possible that there was a link between participants subjective workload and their speed, with higher workload being associated with lower speed. Alternatively, it can be posited that as the high locality trial offered participants a greater number of local landmark cues with known dimensions, which could be used to judge relative speed of travel in addition to the vehicles' speedometer. Further research is needed to explore this finding in greater depth.

### 3.4 Lessons Learnt and Future Work

This study provided initial pilot data regarding the use of a simulation environment based on a real-world environment that was familiar to participants, using specially created land cues. The study highlighted future opportunities for further studies and began to consider the importance of individual differences which should be examined when conducting simulator based research. Further work, recruiting a greater number of participants is needed to support the current findings and allow for the meaningful use of statistical testing. Participants from the current study are all familiar with the area of Southampton that was modeled and driven within the current study. Engaging with a wider demographic, and employing a scale of familiarity is needed in order to establish how locality within a simulation is affected by previous knowledge of the local area. In addition, exploring the impact of variables such as age and driving experience may offer future avenues for research.

A methodological limitation of the study relates to the use of the Fiat Stilo for the on-road component of the study. Participants were not able to drive their own cars due to concerns over insurance, and as such all participants drove the university vehicle. Although the use of a consistent vehicle enables the direct comparison of driving behaviors, participants may have handled this car differently than their own vehicle due to established knowledge of the vehicle's capabilities. In addition, participants may have been less experienced driving with automatic transmission, and as such were required to adapt their behavior. The use of the university vehicle may have influenced subjective ratings recorded in the study and the role of vehicle should be explored further.

Future work should seek to collect objective data during the on-road driving trial including speed and headway to enable direct comparison between these variables for both on road and simulator.

### 3.5 Conclusions

This paper has presented an initial pilot study data exploring the impact of including custom local landmark objects within a simulated driving route. The paper considered the impact of these objects on participants ratings of presence, awareness of speed and self-rated workload. Although, mixed findings were apparent, data suggests that individual differences play a role in the impact of custom objects. Participants with greater reported levels of immersion, particularly "Play/ Gaming", reported greater levels of presence within the high locality route. Furthermore, it appears that the inclusion of the custom objects impacted participants awareness of speed, with participants driving faster in the low locality simulation, which included no landmark custom objects. This can be directly contrasted with data suggesting that participants level of self perceived mental workload was highest in the high locality simulation, suggesting the task was more mentally taxing. Further research is required to fully understand the impact of local landmark cues and high locality simulations on participants performance in the driving laboratory, however it may be the case that the availability of local landmark cues does not always lead to an increased feeling of presence within simulator studies.

**Acknowledgments.**
This work was partially supported by supported by the UK Engineering and Physical Sciences Research Council (EPSRC) grant EP/N022262/1 "Green Adaptive Control for Interconnected Vehicles", EPSRC grant EP/G036896/1 and industrial sponsor Jaguar Land Rover, under the Industry Doctoral Training Centre in Transport and the Environment.
The researchers would like to thank Karen Ghali for assistance in accessing the university instrumented vehicle. The researchers also extend their thanks participants who donated their time to be part of the study.

## References


1. Young, M. S., & Stanton, N. A. (2007). What's skill got to do with it? Vehicle automation and driver mental workload. *Ergonomics*, *50*(8), 1324-1339.
2. Lee, J. D., Caven, B., Haake, S., & Brown, T. L. (2001). Speech-based interaction with in-vehicle computers: The effect of speech-based e-mail on drivers' attention to the roadway. *Human factors*, *43*(4), 631-640.
3. McIlroy, R. C., Stanton, N. A., Godwin, L., & Wood, A. P. (2016) Encouraging eco-driving with visual, auditory and vibrotactile stimuli. *IEEE Transactions on Human Machine Systems, (In Press)*.
4. Shechtman, O., Classen, S., Awadzi, K., & Mann, W. (2009). Comparison of driving errors between on-the-road and simulated driving assessment: a validation study. *Traffic injury prevention*, *10*(4), 379-385.
5. Mets, M. A., Kuipers, E., Senerpont Domis, L. M., Leenders, M., Olivier, B., & Verster, J. C. (2011). Effects of alcohol on highway driving in the STISIM driving simulator. *Human Psychopharmacology: Clinical and Experimental*, *26*(6), 434-439.
6. Ranney, T. A., Baldwin, G. H., Vasko, S. M., & Mazzae, E. N. (2009). *Measuring distraction potential of operating in-vehicle devices* (No. HS-811 231).
7. Yoo, I., Kim, E. J., & Lee, J. H. (2015). Effects of chewing gum on driving performance as evaluated by the STISIM driving simulator. *Journal of physical therapy science*, *27*(6), 1823-1825.
8. Shelton, A. L., & McNamara, T. P. (2001). Systems of spatial reference in human memory. *Cognitive Psychology, 43,* 274–310.
9. Siegel, A. W., & White, S. H. (1975). The development of spatial representations of large-scale environments. In H. W. Reese (Ed.).Advances in child development and behaviour, 10, 9–55. New York: Academic Press.
10. Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and virtual environments*, *7*(3), 225-240.
11. Witmer, B. G., & Singer, M. J. (1994). *Measuring immersion in virtual environments*. (ARI Technical Report 1014). Alexandria, VA: U. S. Army Research Institute for the Behavioural and Social Sciences.
12. Banks, V. A., Stanton, N. A., & Harvey, C. (2014). What the drivers do and do not tell you: using verbal protocol analysis to investigate driver behaviour in emergency situations. *Ergonomics*, *57*(3), 332-342.