Systematic Behavioural Analysis of Pedestrian and Autonomous Vehicle Interactions using Virtual Immersive Reality Environment

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March 15, 2018

1 Introduction

As autonomous vehicles are going to find their ways on streets in near future, they will have a significant impact on dynamics of urban areas. For instance, reducing streets' lane width, increasing public spaces, sidewalk and bike lane width, restrictions on roads based on real-time demand, managing traffic gaps, setting lower speed limits and assuring pedestrians and bikes safety with the ability to detect them, are some of the possible changes in future urban areas [1]. Various researchers have studied the technology, adaption rate, demands, etc. of autonomous vehicles. However, according to a survey for recognizing the barriers to cities' AV efforts, the unclarity of issues that require city action has still remained as one of the biggest obstacles for preparing cities for autonomous vehicles [2].

This proposed study aims to concentrate on features of future streets and autonomous vehicles' traffic parameters that relate to pedestrians. We quantify the effects of specific AV traffic parameters and future streets' geometric designs on pedestrians' walking behaviour. To do so a virtual Reality based experimental design is generated.

To observe the effects of multiple attribute simultaneously, an optimal design will be designed. In optimal designs, an efficient combination of attribute levels to be tested in the experiment is defined. After generating an experimental design, it is important to implement the design in a way that participants fully understand and realistically take part in the experiment. To improve realism of experiments, visual information can be used. Virtual Reality (VR) tools have made it possible to create an immersive and controlled environment. Scenarios used in experiments may be difficult or impossible to apply on real roads, due to reasons such as dangerous implementations or lack of infrastructures. VR simulator allows running such

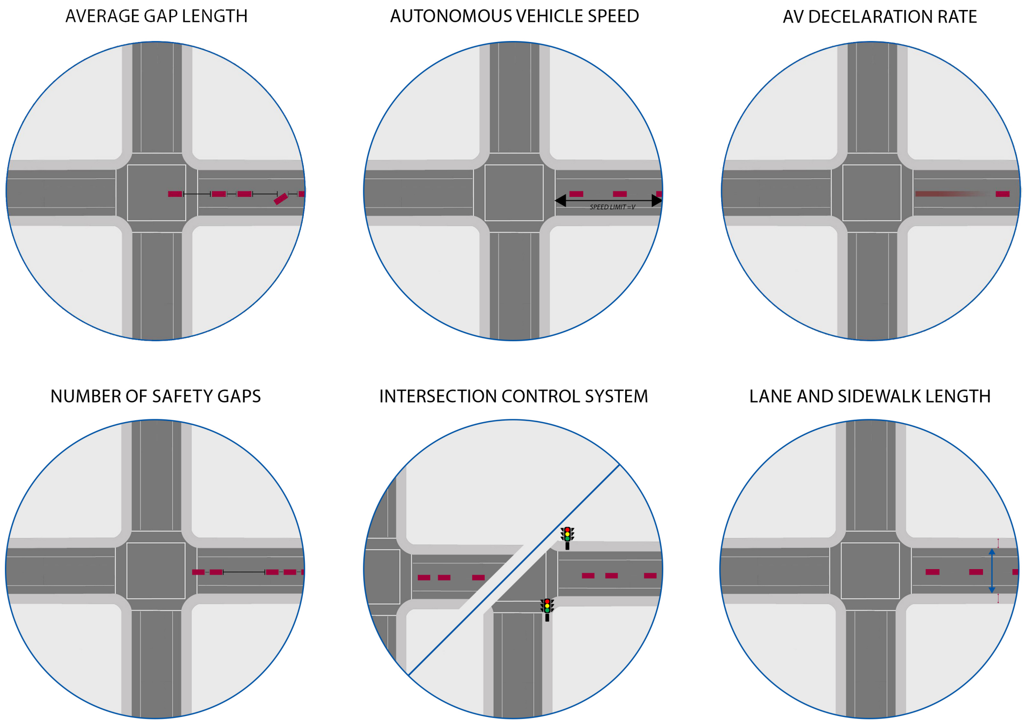

Figure 1: Defined attributes for automated intersection

scenarios, along with scenarios containing new technologies or services that participants have limited mental image of, or expressing their features in textual context is difficult.

2 Methodology

In this study, we use a tool developed in-house, Virtual Immersive Reality Environment (VIRE), to conduct a D-optimal experiment to analyze the effects of some AV-related parameters on different pedestrians safety and walking behaviour. Introduced in [3], VIRE uses Head Mounted Display and virtual reality to enable interactive, immersive and complex simulated scenarios. Hypothetical traffic simulations can be projected directly to eyes of users. VIRE consists of four main systems working together: a 3D scenario is created based on theoretical experiment design, traffic movements is simulated, positions and interactions of dynamic objects are projected onto Head Mounted Display, and finally responses from users are recorded.

National Association of City Transportation Officials recently published a blueprint for autonomous urbanism. This blue print suggests, prior to having AVs on the streets, it is important to explore potential changes carefully to have efficient, safe and pedestrian friendly streets. Based on related literature, some traffic and design attributes are defined: AV speed limit v, number of safety gaps n, average gap length μ, AV deceleration rate when approaching intersection, sidewalk and lane width. These attributes are depicted in figure 1 participants will be asked to cross a hypothetical intersection, in which all the vehicles crossing are autonomous vehicles. Gerrard and Church intersection in downtown Toronto is simulated in virtual reality for this purpose, so that participants are familiar with the intersection settings. Pattern of autonomous vehicles' movements will be controlled by a Poisson distribution with mean μ. In each trial, n safety gaps will be randomly inserted. These safety gaps are in a way that if a pedestrian crosses the street during them, the vehicle would not need to stop. Different levels are defined for each attribute. More than 300 participants are going to take part in the experiment. Basic socio-demographic information of participants is also recorded. To observe the effects of these attributes on some defined measures of pedestrian safety and walking behaviour, a D-Optimal design will then be used. These measure are: *a)* number of successful attempts, *b)* Post-encroachment-time PET, *c)* Time-to-collision TTC, *d)* pedestrian waiting time, *e)* pedestrian head and eye movements, *f)* Change in pedestrian stress level while crossing.

Among these measures, number of successful attempts is considered as the main dependent variable. a D-Optimal design will then be developed based on this dependent variable and other independent variables measured. Each participant would go through 5 trials of each task. The horizon of each trial is 2 minutes. If the participant fails to cross the intersection in 2 minutes, the trial would be recorded as a fail attempt. Finally, an in-depth statistical analysis of AV-related attributes effects on pedestrians' walking behaviour and safety measures will be conducted.

3 Conclusion

This first of a kind study will result in insights that can help to propose primary standards for some features of autonomous vehicles in highly-walkable urban areas. The effects of speed limits, gap lengths, number of safety gaps, deceleration rate, intersection control system, sidewalk and lane width on a set of pedestrian walking behavior will be studied. Autonomous vehicles can provide a unique opportunity for redesigning and rethinking traditional urban transportation systems. By exploring various aspects of future streets' in the presence of autonomous vehicles, this study helps cities plan sustainable policies, geometric design changes and traffic regulations. In order to develop a human-oriented perspective of future urban areas, approach taken in this study is based on pedestrians' concerns. One of the challenges in these types of research is the absence of real world experiences to validate the results. In order to overcome this problem, simulating street conditions as precisely and realistically as possible would be helpful. The future steps for this project is to develop advanced predictive models of behaviour for other dependent variables defined.

Refrences

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