Accident Analysis and Prevention 100 (2017) 53–58

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Validation of a bicycle simulator for road safety research

Steve O'Hern[a,*], Jennie Oxley[a], Mark Stevenson[b]

[a] Monash University Accident Research Centre, Australia
[b] Melbourne School of Design/Melbourne School of Engineering, The University of Melbourne, Australia

ARTICLE INFO

Article history:
Received 28 September 2016
Received in revised form 7 December 2016
Accepted 5 January 2017

Keywords:
Bicycle simulator
Validation study

ABSTRACT

The study's aim was to assess the behavioural validity of participants using of a newly developed bicycle simulator with respect to a range of cycling performance measures collected both using the cycling simulator and on-road. The validation study consisted of a within-subjects study design comparing participants riding on-road with riding in the simulator.

The study recruited 26 participants ranging in age from 18 to 35 years (M = 25.0, SD = 4.8). Absolute validity was established for measures of spatial positioning including average lane position, deviation in lane position and average passing distance from kerbside parked cars. Relative validity was established for the average speed of cyclists and their speed reduction on approach to intersections and a degree of validity was established for aspects of the participants head movements on approach to intersections.

The study found evidence to suggest that aspects of cyclist behaviour can be investigated using the bicycle simulator, however further validation research may be required in order to more comprehensively validate looking behaviours, more complex performance measures and for a wider age range of cyclists.

1. Introduction

Driving simulators offer a range of benefits compared to on-road studies by creating an inherently safe environment to consistently and systematically create traffic scenarios, in a cost effective manner, that would be difficult (due to the inherent risks for the participant) in a real world environment (Blana, 1996; Godley et al., 2002; Meuleners and Fraser, 2015; Moroney and Lilienthal, 2008). For these reasons, the use of simulators continues to grow within the field of road safety research (Meuleners and Fraser, 2015). While the use of automobile simulators has been an active field of road safety research (Blana, 1996; Godley et al., 2002), there is a paucity of simulator-based research investigating the vulnerable road users, especially users of two-wheeled vehicles (Nehaoua et al., 2011). There are various reasons for the disproportionate research efforts (Arioui and Nehaoua, 2013), however, in recent times the increase in the use and mode-share of two-wheeled vehicles combined with the relative growth in the proportion of collisions involving these vehicles has seen research in the field grow (Pucher et al., 2011; Stevenson et al., 2015).

Cyclists, along with motorcyclists, are physically vulnerable road users, especially when they share the road with motor vehicle traffic (Chong et al., 2010; OECD/ITF, 2013; Stevenson et al., 2015). Their vulnerability as road users stems from their limited protection in the event of a collision and their low tolerance to biomechanical forces (OECD/ITF, 2013). In Australia, the proportion of serious and fatal road traffic injuries involving cyclists is increasing (Garrard et al., 2010; Garratt et al., 2015) and it is recognised that there is a growing need to improve cyclist safety to encourage increased participation in this sustainable mode of transport (Stevenson et al., 2015). A recent in-depth investigation of cyclist crashes in Australia highlighted that when riding on-road there is a roughly even split between bicycle only (48%) and multiple vehicle collisions (52%), with multiple vehicle collisions most often associated with a collision involving a car (48%) (Beck et al., 2016).

The Australian Road Safety Strategy recommends the use of evidence-based road designs as one of the key measures to help create safer road environments for cyclists and provide effective measures to reduce cyclist trauma (ATC, 2011; Stevenson et al., 2015).

Simulators provide a cost effective method for preliminary evaluation of evidence-based road designs (Blana, 1996; Moroney and Lilienthal, 2008). The use of simulators allow the researcher to have considerable control over the experiment and simulators allow for scenarios to be repeated consistently (Godley et al., 2002;

* Corresponding author.
E-mail address: steve.ohern@monash.edu (S. O'Hern).

http://dx.doi.org/10.1016/j.aap.2017.01.002

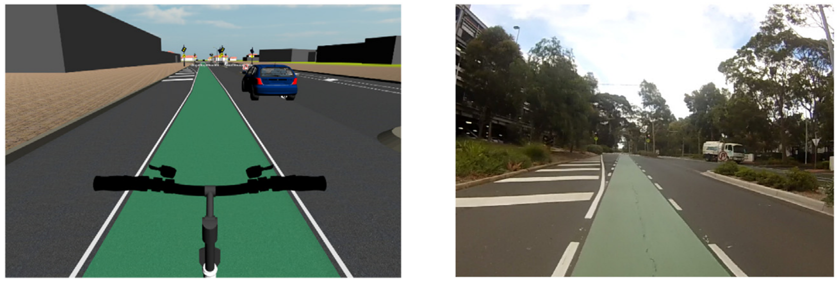

Fig. 1. Comparison between Simulator and On-Road.

Meuleners and Fraser, 2015). Simulators also allow for multiple iterations of designs to be tested and evaluated without the need to construct road infrastructure. Through investigating how road users interact with new road design concepts, it is possible to examine the safety benefits of interventions and identify some relevant unexpected behaviours and issues with the concepts prior to construction. Furthermore, the inherently safe simulator environment allows for potentially dangerous traffic conditions and behaviours to be examined, while removing the physical risks to the participants and other road users (Godley et al., 2002; Rudin-Brown et al., 2009).

While simulators offer a range of benefits for research, in order for the results of simulator-based studies to be meaningful it is essential that the correspondence between the real world and the simulated environment is the same, or at least sufficient, to produce valid results (Kaptein et al., 1996; Törnros, 1998). For simulator studies it is the performance of the participants that is under investigation, not the fidelity of the simulator itself (Rudin-Brown et al., 2009). The simulator does not have to be identical to the real experience but it must be able to sufficiently replicate the specific task or behaviour that is under investigation (Rudin-Brown et al., 2009). Further, it is particularly important that the road-user behaviours elicited in response to events in the simulator are comparable to responses and behaviours in real world traffic situations (Törnros, 1998). In order to meet this requirement, simulators are often validated against a set of key performance measures to assess the correlation between results. Traditionally simulator validations studies have relied on measures such as speed, speed adaptation, lane keeping and variation in lateral position (Blana and Golias, 2002; Godley et al., 2002; Törnros, 1998; Underwood et al., 2011).

The aim of this study was to assess the validity of the performance of participants using a newly developed bicycle simulator, compared to riding on-road. The study sought to assess the behavioural validity of the simulator compared to a selected range of performance measures for cycling on-road including the average and standard deviation in lane position of the cyclist when riding in a bicycle lane, average passing distance when passing parallel parked cars, the speed profile of the cyclist, speed reduction on approach to a T-intersection and head movements on approach to an intersection. These measures were selected as they relate to basic control functions for a bicycle. The study monitored participants' simulator sickness symptoms to ensure that simulator sickness was not experienced amongst large numbers of participants, which would have the potential to introduce biases into the findings.

Behavioural validity is a measure of the extent to which participants exhibit the same cycling behaviours using the simulator as they do with riding on-road (Blaauw, 1982; Godley et al., 2002). Behavioural validity was assessed on two levels; absolute validity and relative validity, where absolute validity refers to the situation where simulated and on-road data provide the same numerical results and relative validity refers to the situation where the results differ between the two tasks but exhibit similar patterns in terms of their magnitude or direction (Godley et al., 2002).

2. Materials and methods

2.1. Study design

The validation study consisted of a within-subjects study design comparing selected measures of performance of participants riding on-road with riding in the simulator (Fig. 1). A within-subjects study design was chosen to control for variance between the participants undertaking the study. To control for carryover effects, participants undertook each stage of the study on different days. The order that participants performed the on-road and simulator components was counterbalanced, however due to the influence of weather the order was not randomised, with two participants completing the simulator component first when there was adverse weather on their first day of testing when they were originally allocated to perform the on-road task first.

2.2. Participants

A convenience sample of 30 participants (22 males and 8 females) were recruited for the study. Power calculations were performed to identify the required number of participants for the study, based on the proposed statistical techniques and within group study design. Participants were required to be over 18 years of age and be comfortable riding a bicycle on local roads. Participants were excluded from the study if they had medical conditions that might be aggravated due to exercise or using the bicycle simulator including epilepsy, high blood pressure, having previously experienced a heart attack, or if they had a history of suffering from either motion sickness or simulator sickness. Participants who required glasses for normal vision were also excluded from the study (participants who required contact lenses to correct their visions were accepted into the study). This exclusion criteria was necessary as it can be difficult for some glasses to be worn at the same time as the head mounted display.

Recruitment was undertaken by placing flyers around Monash University Clayton campus. An advertisement was also placed in the Monash Memo, which is a weekly e-newsletter sent to Monash University staff.

The research protocol for the study was reviewed and approved by the Monash University Human Research Ethics Committee. Participants received a $50AUD gift voucher for participating in the study and to compensate them for their time and travel expenses.

2.3. Data collection

2.3.1. Survey component

Participants completed a short questionnaire addressing demographic characteristics and cycling experience information.