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The use of adaptation to reduce simulator sickness in driving assessment and research

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ABSTRACT

The technical advancement of driving simulators has decreased their cost and increased both their accuracy and fidelity. This makes them a useful tool for examining driving behavior in risky or unique situations. With the approaching increase of older licensed drivers due to aging of the baby boomers, driving simulators will be important for conducting driving research and evaluations for older adults. With these simulator technologies, some people may experience significant effects of a unique form of motion sickness, known as simulator sickness. These effects may be more pronounced in older adults. The present study examined the feasibility of an intervention to attenuate symptoms of simulator sickness in drivers participating in a study of a driving evaluation protocol. Prior to beginning the experiment, the experimental groups did not differ in subjective simulator sickness scores as indicated by Revised Simulator Sickness Questionnaire scores (all $p > 0.5$). Participants who experienced a two-day delay between an initial acclimation to the driving simulator and the driving session experienced fewer simulator sickness symptoms as indicated by RSSQ total severity scores than participants who did not receive a two-day delay ($F(1,88) = 4.54$, $p = .036$, partial $\eta^2 = .049$). These findings have implications for improving client well-being and potentially increasing acceptance of driving simulation for driving evaluations and for driving safety research.

1. Introduction

According to statistics from the Federal Highway Administration, from 1997 to 2010 there was a 28 percent increase in the number of licensed drivers over the age of 65 years old. The increase in older licensed drivers is of concern because these drivers may eventually suffer from cognitive declines due to aging (Craik and Salthouse, 2007) that may affect their driving performance. While older drivers are not necessarily more likely than younger drivers to be involved in a crash, they are more likely to be killed or injured in such a crash. It is important to help older drivers avoid crashes while helping them maintain the ability to drive safely.

This will necessitate research on and evaluation of older drivers in a way that is safe and informative. One approach to this is to use simulators because it is possible to standardize and quantify evaluation procedures while in a safe environment. Unfortunately, some people, notably older adults, experience simulator sickness in simulators. In fact, the authors have noted considerable participant attrition rates in simulator-based experiments. Thus, making driving simulators more accessible to older adults might be viewed as advantageous for driving safety and accident prevention.

Simulator sickness has been described as a unique form of motion sickness (Rizzo et al., 2003). Many studies and anecdotal reports indicate that older adults suffer greater simulator sickness symptoms than other groups (Stanney et al., 2002; Freund and Green, 2006; Mullen et al., 2010). Indeed, in a study examining left-hand turning ability older adult attrition was 40 percent whereas younger adult attrition was 14 percent (Edwards et al., 2004). These data and the authors' own observations suggest a need to attenuate simulator sickness in order to make simulation available to more drivers. It is therefore important to explore the phenomenon of simulator sickness and attempt to understand interventions that have utility for reducing it.

1.1. Simulator sickness

Simulator sickness is a phenomenon that is affected by simulator features and participant characteristics. It produces symptoms that are similar to, but typically less severe than, those of motion sickness such as nausea, ocular discomfort, and disorientation (Kennedy et al., 1993).

In this regard, the sensory conflict theory of motion sickness provides an important framework for understanding simulator

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sickness (Reason and Brand, 1975). The theory states that the symptoms of motion sickness are a result of conflicting visual and vestibular cues. In motion sickness, such as that experienced by some while attempting to read in a moving vehicle, vestibular motion cues are coupled with an absence of visual motion cues. In contrast, in simulator sickness visual motion cues are coupled with an absence of vestibular motion cues.

Not every individual experiences simulator sickness to the same extent, even in identical situations. Reason's (1978) neural mismatch model of sensory conflict theory states that susceptibility is a product of an individual's overall experience with motion sickness. This would suggest that older adults would be less susceptible to motion sickness than younger adults because they have more exposure to situations that would produce motion sickness.

In contrast, several studies have found that older participants are *more* susceptible to simulator sickness than other age groups (Edwards et al., 2004; Park et al., 2004; Brooks et al., 2010). This may be due to a lack of experience with simulated environments on the part of older adults. If this is indeed the case, then providing some experience with the simulator prior to prolonged exposure in research or clinical settings may improve tolerance. Providing long-term exposure to a clinical simulator is not a practical solution, given the required costs and the need for the client to return for many sessions.

One approach to reduce symptoms of simulator sickness is the use of adaptation or time delay. Results from several studies have shown decreased simulator sickness symptoms with repeated exposure within and between days (Gower et al., 1987; Hu and Stern, 1999; Hill and Howarth, 2000; Howarth and Hodder, 2008; Teasdale et al., 2009). This reduction in simulator sickness symptoms due to time delay between simulator sessions has been shown to persist up to a month or longer (Hu and Stern, 1999). Howarth and Hodder (2008) found that simulator sickness symptoms decreased over 10 days of simulator exposure with a session on each day. Teasdale et al. (2009) found that older adults' (ages 65–84 years old) simulator sickness symptoms as measured by a subjective questionnaire decreased over subsequent simulator sessions. They found that older adults adapted to simulation over several sessions. After the fifth session the older adults did not differ from the initial baseline condition on simulator sickness scores. These results indicate that adaptation could be used to attenuate simulator sickness symptoms. Therefore, the goal of the present research was to determine whether a short-term exposure session which preceded the clinical exposure session by two days would improve tolerance.

1.2. Present study

For the present purposes, we will use the term *acclimation* for the name of the first brief exposure to the simulator that was used to allow the participants to adjust to the simulator. We will use the term *adaptation* to mean an initial, brief simulator acclimation session followed two days afterward by the full simulator test protocol. We should also note that Howarth and Hodder (2008) have used the term habituation to indicate adaptation with a time delay. To avoid confusion with the many definitions of that term, we will be using "adaptation".

The present study was conducted in the context of a larger project to validate a clinical driving evaluation protocol. Investigation of the adaptation's effectiveness was a secondary aim of that larger project and placed several constraints upon the design. A complete description of the validation study is beyond the scope of this paper, but descriptions of the cognitive tasks and simulator task sessions can be found in Tuttle et al. (2009) and Backs et al. (2011).

Group	Session 1				LAG DAY	Session 2			
Lag n = 48	*RSSQ C1*	Acclimation	*RSSQ C2*	Cognitive Testing		*RSSQ D3*	Acclimation	Driving Testing	*RSSQ D4*
Immediate n = 47	*RSSQ D1*	Acclimation	Driving Testing	*RSSQ D2*		*RSSQ C3*	Acclimation*	*RSSQ C4*	Cognitive Testing

C = computer session; D = driving session

*This acclimation did not include the auto-drive and cruise control scenarios, so was somewhat shorter than the corresponding computer-session adaptation in the Lag group.

Fig. 1. Order of tasks and RSSQ administrations by session and group.

We examined the effects of an adaptation on self-reported simulator sickness scores while in a high fidelity driving simulator. Participants were given a simulator sickness acclimation before beginning a cognitive evaluation session and again before beginning the driving session in the simulator. The sessions were administered on separate days. The order of these sessions was counterbalanced between participants. Thus, some participants participated in an acclimation session two days before a driving session (i.e., the adaptation; the Lag group) and others participated in the driving session immediately after the acclimation (the immediate group). Fig. 1 shows the order of the two groups. Revised Simulator Sickness Questionnaire (RSSQ) scores were obtained before and after the acclimation during the cognitive session and before and after the driving session which also contained an acclimation. Thus, we obtained four scores for each individual.

1.3. Hypotheses

As the main goal was to determine whether the adaptation would reduce simulator sickness symptoms, the primary hypothesis relates to the effect of the adaptation. Prior work noted above also suggested that there would be an age effect. We investigated both hypotheses.

1.3.1. Adaptation

The main prediction involved post-driving session RSSQ scores. We predicted that the Lag group would report lower post-driving RSSQ total severity scores than the immediate group. Furthermore, we predicted a similar significant effect of group on RSSQ nausea scores. Based on unpublished data from our lab, we made no predictions of the effect of group (lag, immediate) on disorientation, ocular discomfort or strain/confusion RSSQ scores.

1.3.2. Age

Because of prior experience with participants of varying ages in simulated driving in our laboratory (Cassavaugh et al., 2009; Domeyer, 2009), we predicted a significant effect of age on total severity and nausea with older adults reporting higher scores (more sickness). Again, based on findings from Domeyer (2009) we did not predict a similar effect on the other subscale scores (disorientation, ocular discomfort, and strain/confusion).

2. Materials and methods

2.1. Participants

Total participants were 120 (40 young; 40 middle; 40 old) individuals recruited for a driving assessment protocol validation. They were either students from Central Michigan University recruited through the psychology subject pool or members of the community recruited through flyers placed at surrounding organizations. Students were given course credit for their participation. Members of the community were paid $28 per hour for their participation. Participants were assigned to groups by order of recruitment.