Transportation Research Part F 48 (2017) 28–37

Contents lists available at ScienceDirect

Transportation Research Part F

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

Using simulation to assess the ability of youth to safely operate tractors

Barbara Marlenga [a,*], Richard L. Berg [b], William Pickett [c], Timothy Brown [d], Nicole Becklinger [d], David C. Schwebel [e]

[a] National Children's Center for Rural and Agricultural Health and Safety, Marshfield Clinic Research Foundation, Marshfield, WI, USA
[b] Biomedical Informatics Research Center, Marshfield Clinic Research Foundation, Marshfield, WI, USA
[c] Department of Public Health Sciences, Queen's University, Kingston, Ontario, Canada
[d] National Advanced Driving Simulator, University of Iowa, Iowa City, IA, USA
[e] Department of Psychology, University of Alabama at Birmingham, Birmingham, AL, USA

A R T I C L E I N F O

Article history:
Received 5 May 2015
Received in revised form 28 April 2016
Accepted 24 April 2017
Available online 19 May 2017

Keywords:
Tractors
Children
Farm injury
Driving simulations
Child development

A B S T R A C T

Background: Operating farm tractors is dangerous for children. Recent studies document mismatches between children and physical requirements for operating tractors. The role of cognition has not been studied, because such research conducted in real-life situations places youth at risk. The objective of this study was to evaluate the feasibility and psychometric properties of a simulated virtual tractor environment to examine how children's age and development impacts safe tractor operations.
Methods: Fifty-five male youth ages 10–17 living/working on farms with experience driving tractors tested the virtual environment and simulation modules. Six adult male farmers were recruited as a reference group to compare youth performance with adults.
Results: The simulation had adequate face validity with realism scores reported between "somewhat" and "quite" realistic. Internal reliability of the simulation was excellent, as demonstrated by highly significant intraclass correlations for key indicators of performance (speeds and hazard clearances). While there was some evidence for construct validity, as indicated by trends in performance across the age groups, findings were mixed.
Conclusion: Study findings support using simulation for assessing the abilities of children to safely operate tractors.

1. Introduction

Agriculture is the most hazardous industry for young workers in the United States (Centers for Disease Control, 2003). Farm tractors cause the majority of fatal injuries to youth working in agriculture (Castillo, Adekoya, & Myers, 1999; Hard & Myers, 2006; Pickett, Brison, & Hoey, 1995) and therefore, represent a leading priority for occupational injury prevention (Centers for Disease Control, 2003).

Youth begin operating tractors at very young ages (Browning, Westneat, & Szeluga, 2001; Marlenga, Pickett, & Berg, 2001a, 2001b; Park et al., 2003). In the United States, most farms are exempt from occupational safety and health regulations

* Corresponding author.
E-mail addresses: marlenga.barbara@mcrf.mfldclin.edu (B. Marlenga), berg.richard@mcrf.mfldclin.edu (R.L. Berg), pickettw@post.queensu.ca (W. Pickett), timothy-l-brown@uiowa.edu (T. Brown), nicole-becklinger@uiowa.edu (N. Becklinger), schwebel@uab.edu (D.C. Schwebel).

http://dx.doi.org/10.1016/j.trf.2017.04.021
1369-8478/

(United States Department of Labor (US DOL), 2013) and child labor regulations (United States Department of Labor (US DOL), 2007), thus allowing parents to decide when their children are ready to begin operating tractors and when they are ready for complex tractor work. Furthermore, most states offer driver's license exemptions for tractor operation on highways, thereby allowing youth to operate tractors legally on highways without any formal training or licensing (Doty & Marlenga, 2006).

Several factors place youth at risk for tractor-related injuries. Perhaps best documented is children's relative physical size. Children have shorter arms, legs, and torsos than adults; they are also weaker physically (Fathallah, Chang, Berg, Pickett, & Marlenga, 2008). Recent studies document mismatches between children and the physical requirements for tractor operations (Chang, Fathallah, Pickett, Miller, & Marlenga, 2010; Fathallah, Chang, Pickett, & Marlenga, 2009; Fathallah et al., 2008), illustrating children's inability to see hazards over tractor dashes and to reach levers and controls with their hands and feet. Children's comparative physical weakness may also contribute to tractor-related crashes and injuries because they may not have strength to fully activate the clutch and brakes to reduce speed or stop (Fathallah et al., 2008).

Risks associated with youth tractor operation extend beyond physical limitations, however (Schwebel & Pickett, 2012). Another significant factor is cognitive development. Substantial cognitive development occurs during the pre-teen and teen years, including growth in decision-making, perception, judgment, and executive function (Bjorklund, 2012; Bornstein & Lamb, 2005). Safe tractor operation requires a wide range of cognitive skills (Schwebel & Pickett, 2012), including these, so it seems likely that younger children, with lesser developed cognitive skills, will be riskier tractor operators. However, little empirical evidence exists on this topic. Epidemiological evidence indicates common causes of fatal and traumatic injury involving youth on farm tractors include rollovers, bystander run overs, and collisions (Hard & Myers, 2006; Pickett, Hartling, Brison, & Guernsey, 1999; Pickett et al., 2001), all of which imply functional loss of vehicle control or failure to avoid hazards that may result from insufficient cognitive skills to safely operate tractors in complex situations. But studies aimed at verifying such ideas are lacking, partly because of ethical limitations of experimental or observational study designs where youth operate tractors in the real world. An alternative – proven useful to study cognitive developmental risks for youth pedestrians (Meir, Parmet, & Oron-Gilad, 2013; Schwebel, Gaines, & Severson, 2008; Stavrinos, Byington, & Schwebel, 2009), bicyclists (Plumert, Kearney, & Cremer, 2004; Plumert, Kearney, Cremer, Recker, & Strutt, 2011), and novice drivers (Oron-Gilad & Parmet, 2014; Parmet, Borowsky, Yona, & Oron-Gilad, 2014)—is to study children in a simulated virtual environment.

The aim of this study was to evaluate the feasibility and psychometric properties of a simulated virtual tractor environment using operator-in-the-loop simulation (that is, where the participants control the operation of the tractor themselves) to examine how children's age and development may impact safe tractor operation. We posed three hypotheses: (a) the newly-developed simulation would demonstrate face validity (realism) for both youth and adult users; (b) the simulation would show internal reliability, whereby users who performed in a certain way during part of the simulation would tend to perform that way consistently throughout the simulation; and (c) the simulation would show construct validity by documenting the role of age and development in safe tractor operation, with younger participants behaving differently and more riskily than older participants.

2. Methods

2.1. Participants and protocol

Fifty-five male youth, ages 10–17 years, who lived or worked on farms and had experience with tractor operations participated (see Table 1 for sample description). This convenience sample of youth was recruited using various methods including word of mouth and in-person distribution of flyers at local 4-H and FFA events, as well as rural schools near to the testing site. All subjects were male, as 96% of youth tractor fatalities occur to males (Hard & Myers, 2006). A convenience sample of six adult male farmers (ages 34–49 years, median 44) with tractor experience, who were not related to the youth participants, was recruited as a secondary reference group. Participants were largely white and not Hispanic or Latino (58/61), reflecting the local farm population. Youth ages 10–12 years provided informed assent, youth ages 13–17 informed consent, and all parents and adult participants signed informed consent. The institutional review boards of University of Iowa and Marshfield Clinic Research Foundation reviewed and approved the protocol.

2.2. Simulator specifications

The simulation was conducted at the National Advanced Driving Simulator (NADS) facility at University of Iowa's Research Park. Participants drove a tractor with a towed mower in the NADS-2 simulator through a simulated farm environment (S1 Fig.). The NADS-2 simulator is a medium size, fixed-base driving simulator with an update frequency of at least 60 Hz across subsystems. The simulator consisted of a John Deere 7920 cab equipped with active feel on steering, brake and accelerator pedals, and a fully operational dashboard. The visual system featured three front visual channels with a field of view of 135° and 1400 × 1050 resolution. A 65-in. plasma display was used for the rear channel (1920 × 1080 resolution). An augmented visual display system incorporated two extra projectors as well as horizontal screens on either side of the hood for the near-field visualization of tires and ground with a 1400 × 1050 resolution. All scenarios were completed in a darkened room. A hardware-in-the-loop implementation was adopted to permit use of the electronic control units for the