Applied Ergonomics 53 (2016) 228–240

Contents lists available at ScienceDirect

Applied Ergonomics

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

Ingress and egress motion strategies of elderly and young passengers for the rear seat of minivans with sliding doors

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ARTICLE INFO

Article history:
Received 22 September 2014
Received in revised form
19 July 2015
Accepted 5 October 2015
Available online 26 October 2015

Keywords:
Ingress
Egress
Motion strategies
Passengers
Minivans

ABSTRACT

This study investigates the motion strategies performed by elderly and young passengers while entering and exiting the rear seat of minivans with sliding doors. A minivan mock-up was constructed with four adjustable parameters to represent nine different conditions of vehicle geometry. Ten elderly male participants (66.8 ± 3.8 years old) and ten young male participants (31.5 ± 6.6 years old) were recruited. Each of them entered and exited the minivan mock-up for five times under each condition, and the motion data were acquired by the optical motion capture system. Based on the criteria derived from previous studies, all motions were automatically categorized into seven ingress motion strategies and seven egress motion strategies. Further, the differences among motion strategies are discussed in terms of vehicle factors and passenger factors, which provide clues for future studies.

1. Introduction

Personal transportation helps the elderly people maintain social participation and hence is critical to their quality of life. Among the several choices, automobiles are commonly adopted. Due to the aging effects, many elderly people experience difficulties in driving and thus have no choice but to move from the driver's seats to the passengers' seats. Although this transition makes the task become easier, some of them are still facing challenges while entering and exiting the cars. For example, Petzäll (1995) indicated that suitable dimensions of door width and roof height, as well as adequate positions of handles, are considered by elderly and disabled passengers as the requirements for the safe and comfortable entrances to cars used in taxi services. Besides, it was found that older people have more problems with getting in and out of the car than young people do, which is mainly due to the inadequate configurations of the side sill, roof, and seat cushion (Herriotts, 2005). All these improper designs will hinder the elderly passengers from neutral postures and smooth movements during ingress and egress, which may lead to increased physical load and dissatisfaction. Therefore, investigating the ingress and egress motions of the elderly passengers in reaction to a variety of car types is a quite important issue for automobile manufacturers.

Considering the ingress and egress motions, one topic of interest is how passengers enter and exit the cars differently. For example, according to Kawachi et al. (2005) and Reed and Huang (2008), there are generally two ingress motion strategies including the head-first strategy and the hip-first strategy, depending on whether the head or the hip passes through the door frame first while getting into the car. In addition, Ait El Menceur et al. (2009) used the sequence of foot/hip placement and joint articulation such as trunk flexion/extension and internal/external rotation as the indicators to identify six ingress motion strategies for the driver's seat of small cars and minivans, including lateral sliding, backward motion, median motion, forward motion, trunk backward, and trunk forward. Among these findings, all of them were interpreted based on the results of kinematic analyses, which usually require great time and effort for the reconstruction of motion data. Thus, a

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http://dx.doi.org/10.1016/j.apergo.2015.10.005
0003-6870/

quick method for identifying ingress/egress motion strategies following these criteria would be of great help.

On the other hand, it is particularly interesting to further know about the difference between elderly and young passengers in their ingress/egress motion strategies, which may be caused by aging effects such as impaired muscle strengths and balance abilities. Nakahama et al. (2001) identified three specific motion patterns of older people that require hand supports to facilitate ingress and egress. Chateauroux and Wang (2010) also observed a unique egress strategy performed only by older drivers for four types of cars, in which hand supports are necessary for helping them exit the car more easily. In addition, as reported by Chateauroux et al. (2007), car accessibility is considered to be an important factor in the elderly drivers' car choice. More specifically, difficulties of the elderly drivers mainly depend on their body height, physical condition, and vehicle geometry. Among the several size parameters, the width and height of the door frame were concluded as critical ones. Thus, it is also of concern how the ingress/egress motion strategy relates to car design and the passenger's subjective feelings.

For elderly passengers, minivans are usually considered as one the most suitable choices because of the larger entrance, higher seats, and some other devices such as sliding doors or assisting handgrips (Bodenmiller et al., 2002). However, there are quite few studies focusing on the ingress and egress motion for this type of cars used by elderly passengers. Therefore, the objective of this study is to categorize how elderly passengers would enter and exit the rear seat of minivans with sliding doors, as well as investigating how the strategies differ from those performed by young passengers.

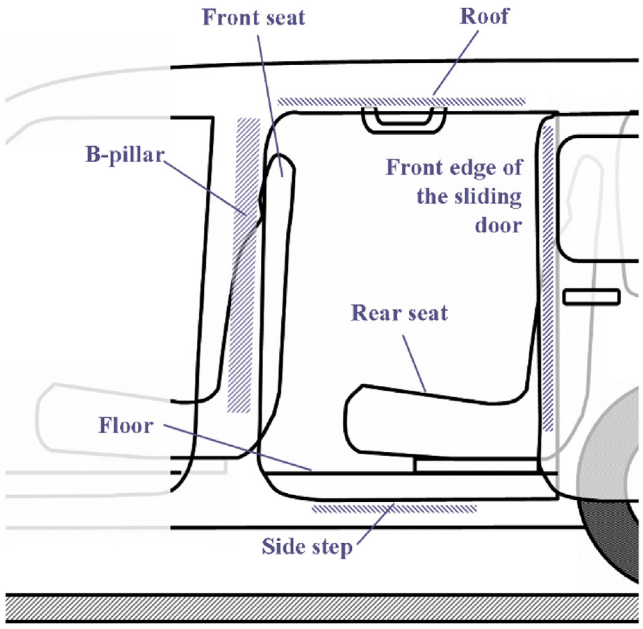

Fig. 2. Illustration of the corresponding car components.

2. Method

2.1. Data collection

In order to represent the varying vehicle geometry, a minivan mock-up was constructed with four adjustable size parameters, including roof height, door width, floor height, and (rear) seat height, as illustrated in Fig. 1 and Fig. 2. Adjustable dimensions of the mock-up were determined through the survey of existing minivans. Considering the left hand traffic in Japan, this mock-up was designed to simulate the case that the passenger enters and exits the minivan from the left hand side of the rear seat. Besides, since the need for hand support is also of great concern, a set of headrest and seat back is provided in front of the rear seat as the front passenger seat, so that the participant may put either hand or both hands on it to keep better balance during ingress and egress. In case that the participant's body might be hidden by the front passenger seat from the cameras, the set of headrest and seat back is connected to the base frame of minivan mock-up by only one inclined pillar. As shown in Fig. 1, a piece of cushion made of the same material as the headrest is attached to the upper part of the

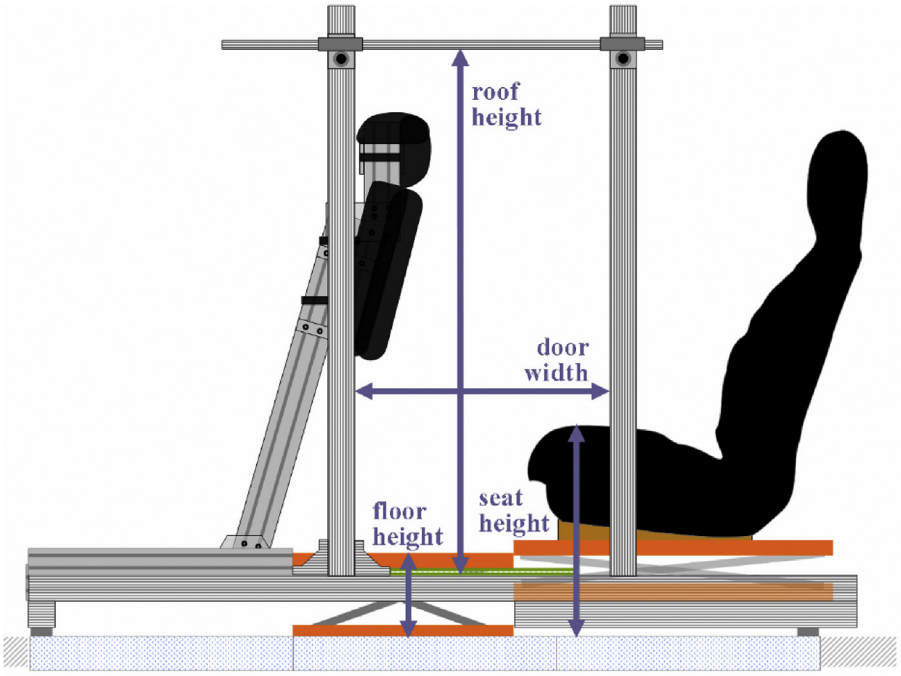

Fig. 1. Illustration of the minivan mockup.