

2021

24th Presentation Session for Traffic Accident Investigations, Analysis, and Research

**Unsafe Behavioral Tendencies During Driving and Accident Prevention from the
Viewpoint of Driver Behavior Formation in Older Adults**

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1. Background of research and purpose

Despite having a decreasing overall population, Japan's population of those aged 65 and older is increasing¹⁾, as are the number of license holders aged 75 and older²⁾. In super-aging societies such as that of Japan, serious accidents caused by older adult drivers are also occurring, requiring the need for more effective measures aimed at older adult drivers.

The Institute for Traffic Accident Research and Data Analysis (hereinafter, ITARDA) conducted joint research³⁾ in collaboration with the Driver's License Department of the Chiba Prefectural Police Headquarters aimed at establishing measures for older adult drivers. As part of this research, they collected data regarding approximately 9,000 participants of driver training courses for older adults (hereinafter, "the training") held in Chiba Prefecture, including data such as "Driving Frequency Questionnaires"⁴⁾ (hereinafter, "questionnaires") and "Driving Behavior Observation Records"⁵⁾ (hereinafter, "observation records"). Afterwards, analysis was performed on driving behaviors deemed as unsafe by evaluators during actual driving performed by older adult drivers, such as driving behaviors evaluated as "dangerous" or "requiring attention"⁶⁾. However, reasons as to why such unsafe driving behaviors are formed in older adults was not considered.

In preventing accidents by older adult drivers, it is important to consider accident prevention measures aimed at older adult drivers themselves in order to help them avoid unsafe behavior and drive safely. For that purpose, research aimed at organizing approaches to systematic accident prevention (Fig. 2) and dependent upon the contexts in which unsafe behavior by older adult drivers is formed is necessary. By gaining an empirical understanding of unsafe behavioral tendencies exhibited by older adult drivers and asking why such unsafe behaviors are formed, this research considers what kinds of support for safe driving, such as "educational support" and "technical support", are appropriate for preventing such unsafe behavior before it occurs. In other words, there is a need for systematic research that sequentially studies methods of supporting safe driving in terms of expressed unsafe behavioral tendencies and responses therefor by focusing on the contexts in which unsafe behavior is formed.

In this research, using unsafe behavioral tendencies observed during actual vehicle driving by older adult drivers as revealed in previous studies³⁾⁶⁾ in which unsafe behavior data from approximately 5,400 individuals was used, approaches of supporting safe driving were considered based on the contexts in which unsafe behaviors were formed and from the perspective of psychology. Specifically, an attempt was made to systematically organize what unsafe behaviors are affected by aging-related changes and driving experience by assuming the context in which older adult drivers form unsafe behaviors and by associating those contexts with unsafe behavioral tendencies and measures for supporting safe driving (Fig. 2).

In this manuscript, unsafe behavior is defined as "older adult driving behavior evaluated by the training instructor as being "dangerous", "requiring attention", "inappropriate", etc."

2. Method

2-1. Analysis data

As subjects for this research, participants in training performed in Chiba Prefecture between September 2018 and September 2019 were used, with the analysis data consisting of a database (with information on 8,928 individuals) which matched training data made up of diagnosis forms and questionnaires.

2-2. Unsafe behavior data

During the on-road driving portion of the training, any time driving school instructors observed or evaluated driving as being "dangerous", "requiring attention", or "inappropriate", they would make entries such as "disregarding traffic signal" or "failure to make safety check" into the remarks column for each item in the diagnosis form (Fig. 1) as they saw fit. During this research, words or phrases related to unsafe behavior were extracted from this descriptive data to generate unique detailed items, with detailed items used only by specific driving schools being excluded. In the end, there were 78 detailed items for unsafe behavior in the unsafe behavior data (binary data consisting of Applicable: 1/Not applicable: 0).

Fig. 1 - Driving Behavior Diagnosis Form

件1 できた項目にチェック(✓)を入れる。箇半は、振り返し実施した回数を示し、実施している箇数のところにチェックを入れる。

図2 指標計部分は、特に重要な指標項目を示す。

標準、規範を定めた規則（もしくは規範）を基盤としており、判断を引き締めること。

3. Unsafe behavioral tendencies in older adult drivers

3-1. Consolidation of detailed items for unsafe behavior by grouping

In order to consolidate the 78 detailed items for unsafe behavior ($N = 5,477$), the Euclidean distance was calculated from the tetrachoric correlation coefficient between all detailed items, hierarchical cluster analysis of variable classification was performed using Ward's method, after which a tree diagram was created from the obtained matrix. Clusters were cut at a distance obtained from the four factors⁶⁾ obtained via factor analysis using the same data and a theoretical interpretation of driving behavior. In this manner, unsafe behaviors by older adult drivers were consolidated into seven types by individually grouping detailed items most resembling corresponding patterns for behavior-related detailed items in order (see prior research³⁾⁶⁾ for details on the analysis performed in 3-1).

3-2. Understanding how unsafe behavioral tendencies are classified

In order to understand the each of the unsafe behavioral (cluster) tendencies summarized in 3-1, the ratio of those individuals who corresponded to even one of the behavior-related detailed items (some individuals corresponded to multiple items) that make up each cluster was calculated. Correspondence analysis was conducted on the relationships between questions on the questionnaire (regarding "driving frequency", "vehicle type" and "transmission type (AT/MT)") and each cluster on the premise that the unsafe behaviors by older adult drivers are formed in response to individual driving experiences (unsafe driving knowledge and schema). In addition, a chi-square test was performed on the relationship between the "age" entered into the questionnaire, as well as "results of the cognitive function test⁷⁾", and each cluster on the premise that unsafe behavior is formed in response to aging-related changes (decline in memory, etc.).

From the results of the above categorical data analysis performed for each cluster, tendencies characterized as unsafe behavior were organized and named based on prior findings. Unsafe behavioral tendencies include (1) "Self-styled driving strategies" consisting of 10 detailed items, (2) "Performing of inappropriate actions" consisting of 6 detailed items, (3) "Automation of habitual actions" consisting of 9 detailed items, (4) "Failure to grasp traffic situations" consisting of 9 detailed items, (5) "Failure to perform necessary actions/procedures" consisting of 23 detailed items, (6) "Failure to perform line-of-sight operation" consisting of 9 detailed items, and (7) "Delayed or forgotten reactions" consisting of 12 detailed items (see prior research³⁾⁶⁾ for details on the analysis performed in 3-2).

4. Unsafe behavioral tendencies and accident prevention as seen from older adult driver behavior formation

This manuscript considered what effects past driving experience and aging have on the formation of unsafe behaviors by older adult drivers using psychological knowledge. This was done by first assuming three contexts for the formation of unsafe behavior. The assumed three contexts were then correlated with seven unsafe behavioral tendencies before organizing the contexts for behavior formation to determine how the unsafe behavioral tendencies organized in 3-2 are formed, before considering approaches to accident prevention that help older adult drivers avoid unsafe behavior while instead conducting safe behavior.

4-1. Contexts for the formation of unsafe behavior by older adult drivers

Although driving is performed using skills acquired during past driving experiences, these driving skill are thought to be hierarchical⁸⁾. It is thought that vehicle operation skills (positioned at the bottom under "Context of behavior formation" in Fig. 2) are first acquired, after which skills for adapting to traffic situations (positioned in the middle under "Context of behavior formation" in Fig. 2) are acquired. From this, it is thought that unsafe behavior by older adult drivers is related to problems with these two driving skills.

Also, driving skills are behaviors formed through learning, with an individual's driving style being created through accumulated driving experience. From this, it is thought that unsafe behavior by older adult drivers is also related to problems with driving styles acquired through past driving experience.

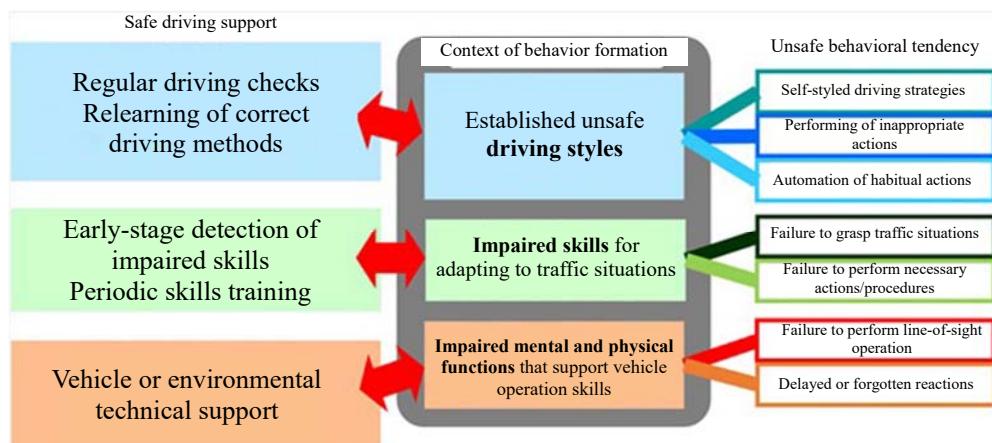


Fig. 2 - Unsafe behavioral tendencies and support for safe driving depending on context of behavior formation

Furthermore, driving is supported by various mental and physical functions such as cognitive function, sensory

function, and muscular strength, which decline with age, although differences exist between individuals. For this reason, it can also be assumed that problems with mental and physical functions that decline with age and which may have an effect on driving skills are a factor in unsafe behavior by older adult drivers.

As seen above, two driving skills, driving style, and three types of aging-related changes are to be considered factors in the formation of unsafe behavior by older adult drivers, for which the three contexts of behavior formation in Fig. 2 are assumed.

From the viewpoint of driving skills, the skilled behavior at the basic level of moving a vehicle is thought to be closely connected to mental and physical functions, for which "impaired mental and physical functions that support vehicle operation skills (Fig. 2)" was assumed to be the context in which unsafe behavior is formed. In addition, the skilled behavior at the level of adapting to traffic situations while driving is thought to not only be influenced by decreased cognitive function, which is required for grasping such situations, but also by impaired driving skills caused by decreased driving frequencies, for which "impaired skills for adapting to traffic situations (Fig. 2)" was assumed to be the context for the formation of unsafe behavior by older adult drivers. Furthermore, from the viewpoint of driving style, when considering individual driving experience (unsafe driving knowledge and ideas), it was assumed that unsafe behavior is formed due to "established unsafe driving styles (Fig. 2)" that were established over many years of driving experience.

4-2. Unsafe behavior due to established unsafe driving styles and support for safe driving

As found in this research, driving which exhibits "self-styled driving strategies" in which behavioral habits acquired through daily driving are strongly expressed, the "performing of inappropriate actions" due to appropriate knowledge, such as how to proceed through intersections, not having been established, and the "automation of habitual actions" due to manners of operational behavior or unique cognition resulting from having driven LL-sized vehicles, etc., are assumed to be influenced by strongly organized and inappropriate driving styles acquired over the course of daily driving experience and are considered to be unsafe behavior representative of a person's own driving style.

These unsafe behaviors are thought to be formed with "established unsafe driving styles (Fig. 2)" as a context, and it is thought that driving risks such as these can be reduced by re-learning correct and safe driving methods at a stage where such behavior can be corrected. Accordingly, a conceivable approach for supporting safe driving is to check drivers daily driving behavior and have them acquire correct driving behavior and relearn said methods before unsafe behavior becomes set in place from middle age.

4-3. Unsafe behavior due to impaired skills for adapting to traffic situations and support for safe driving

Driving which exhibits a "failure to grasp traffic situations" due to the effects of decreased driving frequency, or a "failure to perform necessary actions/procedures" in which dangerous behavior appears during general driving due to multiple effects such as decreased cognitive function or decreased driving frequency, is thought to be caused by problems with driving knowledge (schema) used for responding to situations and acquired through learning, or due to problems with skills for adapting to traffic situations, and is assumed to be unsafe behavior at the level of adapting to traffic situations.

These types of unsafe behavior are thought to be formed with "impaired skills for adapting to traffic situations

(Fig. 2)" as a context, and because driving that had been possible until individuals reach an advanced age is influenced by factors such as decreased driving frequencies and decreased cognitive function, it is thought that these types of unsafe behavior are an expression of behaviors that are no longer possible. Accordingly, support for safe driving could include periodic skill training for drivers with decreased driving frequencies in order to prevent decreases in driving skills, or a scheme in which checks for decreased cognitive function and driving frequency are performed to enable early-stage detection of unsafe behavior related to an inability to grasp traffic situations, a skill which is likely to become impaired, and to provide training therefor. Furthermore, training on driving methods that suit an individual's current abilities is also necessary.

4-4. Unsafe behavior due to impaired mental and physical functions that support vehicle operation skills and support for safe driving

Driving which exhibits a "failure to perform line-of-sight operation" suggestive of decreased cognitive function or an aging-related decline in eye movement ability, or which exhibits "delayed or forgotten reactions" suggestive of effects to memory when performing simple actions or operations and caused by decreases in reaction speed or attention due to age, is that in which an aging-related decline in a driver's fundamental ability to operate a vehicle and perform actions can be observed, and is assumed to be unsafe behavior at the level of vehicle operation.

These types of unsafe behaviors are thought to be formed with "impaired mental and physical functions that support vehicle operation skills (Fig. 2)" as a context, and it is thought that unsafe behavior in current traffic environments results from aging-related barriers that arise and limit drivers from retaining the abilities required for driving. As individuals age, their reaction slows and prevents them from moving their bodies or vehicles smoothly. To enable drivers to drive in a manner suitable for traffic environments despite such circumstances, it is conceivable that technical support could be provided in the form of vehicle-mounted driver-assist technology or by altering road environments in a manner that facilitates driving for older adults.

5. Conclusion

It is not the case that all older adult drivers commit pedal misapplication. Unsafe behavior is expressed in various forms and with varying characteristics, such as behavior at the operation level and behavior at the level of adapting to traffic situations. Furthermore, unsafe behaviors by older adult drivers are not uniformly formed solely due to aging-related declines in mental and physical functions. When considering skilled behaviors that have been learned and aging-related changes, the behaviors of older adult drivers were observed as being formed with contexts such as impaired driving skills due to decreases in driving frequency and cognitive function, as well as established unsafe driving styles acquired through past driving experience.

In order to enable older adult drivers to continue driving safely, unsafe driving behavior must be prevented in advance to prevent accidents. In the future, services or schemes for providing appropriate driving support, either in the form of early-stage educational support or technical support, and depending on the contexts in which the various types of unsafe behavior exhibited by each and every driver are formed, will be required.

<Acknowledgments> This research was based on data used in the joint research program “2019 Investigative Research of Drivers Utilizing Questionnaires Regarding Driving Frequency, etc.” performed in collaboration with the Driver’s License Headquarters of the Traffic Department at the Chiba Prefectural Police Headquarters. A portion of this research was presented at the 62nd Infrastructure Planning and Management Conference held in the fall of 2020, as well as published in the report "Research Study on Older Adult Drivers Using Questionnaires Regarding Driving Frequency, Etc." in 2021. I would like to extend my sincere thanks to all related parties who provided their cooperation with this research at the Chiba Prefectural Designated Driving School Association, Chiba Prefecture's designated driving schools, the Driver’s License Headquarters of the Traffic Department at the Chiba Prefectural Police Headquarters, and the Heiwabashi Motor School.

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