

Study of Driving Error Mechanisms by Inadequate Steering-Pedal Coordination

Yui Kato ¹⁾ Machiko Hiramatsu ¹⁾ Yuka Nakayama ¹⁾ Akihiko Ebina ¹⁾ Naoto Kamide ²⁾
Masataka Ando ²⁾ Atsushi Takamatsu ¹⁾

¹⁾ Nissan Motor Co., Ltd.

¹⁻¹ Morinosatoayama, Atsugi, Kanagawa 243-0123, Japan

²⁾ Kitasato University School of Allied Health Sciences

¹⁻¹⁵⁻¹ Kitasato, Minami-ku, Sagami-hara, Kanagawa 252-0373, Japan

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Purpose

Improper vehicle operation is a major factor in accidents involving elderly drivers, and accidents due to improper steering and pedal misapplication have been increasing with age. To help elderly drivers continue driving safely, it is important to clarify how such improper operations occur and develop support based on this knowledge. We therefore analyzed accident and near-miss videos involving steering errors and pedal misapplication, and hypothesized that difficulty in adjusting appropriate timing and magnitude of steering and pedal inputs during turning is main contributing factor to these errors. In this study, we created tasks to evaluate steering-pedal coordination and aimed to clarify not only operational behavior but also physical and cognitive functions related to this difficulty in coordination.

Method

We conducted steering and pedal control tasks, then measured physical and cognitive functions in 20 elderly and 17 non-elderly drivers. Participants adjusted a cursor frame to match a target circle displayed on a monitor. We gave participants three tasks: a steering-only task, a pedal-only task, and a combined steering-pedal task, in order. Performance, as an index of coordination ability, was defined as the percentage of time the target circle was completely inside the cursor frame. Physical functions were assessed by the 2step test score for walking, grip strength and toe-grip strength for muscle strength, range of motion of upper and lower limb joints for flexibility, and body sway for balance. Cognitive functions were evaluated by Trail Making Test Part A/B (TMT-A/B) for executive function, and by MEDEMIL Drive (MEDEMIL Co., Ltd.) which could measure sustained attention, speed and accuracy of eye movements, depth perception, and visual field.

Result and Discussion

From time-series data in the combined task, we examined pedal control state during steering deviations or vice versa. Steering deviations often coincided with the onset or release of pedal depression or immediately after pedal errors, whereas pedal deviations often coincided with the onset, reversal, or end of steering input (Fig.1). These patterns suggest that when one control is in transition, errors in the other control would be likely to occur, and those errors tend to occur in succession. We think such errors are caused by attention allocation issues: excessive focus on one control leaves too little attention for the other. Especially in elderly drivers, with reduced attention capacity or impaired attention allocation, these errors would occur more often.

Correlation analysis showed that, in the steering-only task, performance was correlated with grip strength, toe-grip strength, anteroposterior(AP) body sway, and sustained attention. In the pedal-only task, performance was correlated with 2step test score and the speed and accuracy of eye movements (Table 1). In the combined task, performance was correlated only with depth perception. In summary, steering control was mainly related to muscle strength and attention; pedal control was related to sensorimotor functions; and combined steering-pedal control was related to visuospatial cognitive functions. If similar relationships could be observed in real-world driving, it may be possible to detect early signs of functional decline in drivers by analysing steering and pedal controls in everyday life.

Conclusion

In the combined steering-pedal task, transitions in steering or pedal control often triggered errors in the other control, and errors occurred in succession, which would be caused by limited capacity and/or impaired control of attention. In addition, correlation analysis showed steering control was related to physical functions, pedal control was related to sensorimotor functions, and combined steering-pedal control was related to visuospatial cognitive functions. These findings indicate that daily driving data would be useful for estimating drivers' functional decline. Future work should be examined to reveal how control errors are related to attention and confirm our findings by using real driving data.

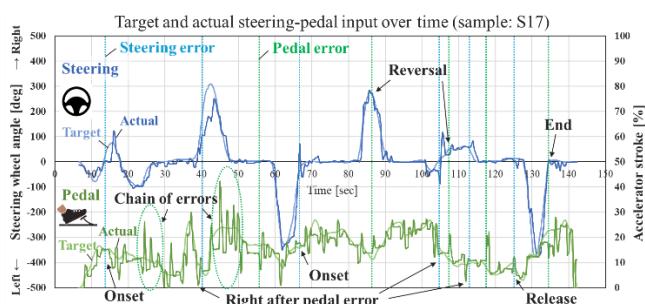


Fig.1 Steering-pedal input over time (one participant)

Table1 Correlation coefficient between each operation task and physical/cognitive functions

	Walking	Muscle strength		Joint range of motion		Balance	MEDEMIL Drive score					TMT	
	2step test score	Grip [kg]	Toe grip [kg]	Wrist dorsiflexion [deg]	Ankle abduction [deg]	Body sway AP-displacement [cm]	Sustained attention	Eye movement speed	Eye movement accuracy	Depth perception	Visual field	Part A [sec]	Part B [sec]
Steering	0.023	0.583**	0.444*	0.033	0.056	-0.465*	0.486*	0.256	-0.210	0.110	0.011	0.167	-0.075
Pedal	0.610**	-0.123	-0.086	0.160	0.434	0.037	-0.178	0.538*	0.472*	0.227	0.006	-0.321	-0.347
Steering-pedal	0.239	0.211	0.300	0.311	0.262	0.169	-0.043	0.090	0.243	0.467*	0.352	-0.022	-0.159

Note. AP-displacement: anteroposterior displacement, * $p < 0.05$, ** $p < 0.01$