# Automotive Controls and Maneuvering Complexity

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**ABSTRACT**

With the development of in-vehicle information systems, a driver is required to handle various types of information while driving. Complicated automotive controls and multi-tasking situations while driving can be often found nowadays. A driver is now required to focus on driving while answering phone calls, listening to music, watching a navigation display and pressing controls. Not only multi-tasks and complicated interface distract the driver, but also driver's ability and environment matters. Vehicle automation is another matter that needs to be discussed with driving complexity. Even through human capability of handling information is beyond our imagination, human mental resource is limited and therefore many car accidents occur every year. The aim of this study is to provide further understanding of automotive controls and maneuvering complexity through extensive literature reviews. In this study, we will examine existing studies on automotive controls and maneuvering complexity from various academic fields. This study will provide many perspectives on how we can see complexity from different point of views and find some design factors that may have an effect on maneuvering complexity. By studying automotive controls and maneuvering complexity, this study will help you understand with control design factors which may have an effect on driver's driving performance. We expect this study will provide an idea to automotive control designers in the field of industry and a general understanding on overall automotive driving complexity, especially on maneuvering complexity in the field of human computer interaction.

Keywords: Automotive Driving Complexity, Maneuvering Complexity, Automotive Controls, Design Factors, HCI

## 1. Introduction

The amount of information that a driver should receive while driving has increased with the development of in-vehicle information systems. Drivers want new technologies to be added to their automotives, but they are distracted and overwhelmed by enormous information caused by those technologies.

Human receive information from their environment through sight, touch, hearing, smell, and taste. While driving, information is perceived through these five senses and a driver recognizes information. After the driver recognizes the information, the driver selects a behavior and performs it (Blackman et al. 2008).

However, capacity of human working memory is limited and the limit is different depending on individual's gender, age, expertise, physical impediments, mental impediments and many individual reasons (Lundqvist and Leman, 2006; Khawaja et al., 2014). Therefore, human have hard time receiving and handling increased information while driving caused by the development of in-vehicle information systems.

Developed in-vehicle information systems have risks to cause driver distraction and improper design (Park, 2011). NHTSA researched on distraction through visual-manual tasks and auditory-vocal tasks to minimize potential driver distraction. According to NHTSA (National Highway Traffic Safety Administration), distracting tasks such as handling a cellular phone or a navigation display can be divided into visual distraction, manual distraction and cognitive distraction.

Distracting tasks we can often find while driving are visual, manual and auditory tasks. Focusing on the road is an essential requirement for a driver while driving. A Driver receives most of information through sight. NHTSA also considered sight as an important sense which distracts a driver and suggested that the eye-off time of a driver should not be over 2 seconds. Manual task is another important task while driving. With the development of technologies, more integrated devices appeared and controls become more complicated with this phenomenon. Various sizes, shapes and types of controls appeared in driving context. Auditory task also plays an important role while driving. When alarm alerts or when we receive feedback, we can often hear auditory signals.

Among other tasks, manual task became more diverse and complicated with appearance of convergence devices (Kang and Yoon, 2006). A driver can answer phone calls by pressing an answering button on a steering wheel and search for a destination by typing a few words on a navigation display. These new functions may help the driver to do multi-tasks possible, but controlling all different types of controls while driving is not an easy job for the driver and safety concerns arise (Horrey et al., 2009).

In addition, vehicle automation effect has been studied since 1990, for its opposite opinions on 'effect of vehicle automation' (Ba and Zhang, 2011; Merat et al., 2012). As new technologies are added to an automotive, need for HVI(Human Vehicle Interface) has increased (Choi et al., 2011). In this study, we will examine on automotive controls and maneuvering complexity to provide some considerable design factors on maneuvering complexity through extensive literature reviews.

## 2. Literature Review

Shackel (1986) claimed that interface should be designed according to cognitive ergonomics and proposed information requirements: user, task and environment. These information requirements together have an effect on a driver while driving and all these requirements should be considered when measuring overall automotive driving complexity. When any of these requirements distracts a driver, it may lead to an accident. According to Wang et al. (2012), tasks other than driving while driving can cause distraction and information overload to a driver.

### 2.1Studies on Complexity

According to many studies, the concept of complexity is too complicated to define (Hollnageland Woods, 2005; Heylighen, 1999). Edmonds (1999) demonstrated that the concept of complexity can be differently defined from different perspectives. The word 'Complexity' came from Latin word 'complexus' meaning twisted together. Heylighen (1999) demonstrated that when two or more components are connected together and difficult to separate them, we can call that as a complex. Even though there are many definitions on complexity, many of these definitions contain three dimensions of complexity on human-system interface: quantity, variety, and interconnections (Xing and Manning, 2005; Xing, 2007).

There are many perspectives on complexity. According to Heylighen (1997), complexity can be seen as a combination of variety and dependency. He also mentioned that it is more complex when components are more distinguished and connected. Ham et al. (2013) classified complexity into physical aspect and functional aspect. Hollnagel and Woods (2005) classified complexity into physical aspect and metrical aspect. Mackay (1950) classified complexity into physical aspect and quantitative aspect. Pringle (1951) classified complexity into spatial aspect and time based aspect.

As operating a system is becoming complicated, may researchers study on relationship between an operator and interface. Maneuvering complexity is often studied by many nuclear power plant studies. Cummings et al. (2010) characterized operator-system interaction complexity at nuclear power plant room and suggested three dimensions of complexity. Blackman et al. (2008) developed SPAR-H method considering some factors that may have influence on operator's performance at nuclear power plant room. The SPAR-H method factors they considered were based on human information processing model which starts from operator's perception to cognition and finally leads to operator's behavior.

### 2.2Studies on Controls

According to Sanders and McCormick (1993), the main function of control is to transfer information. European Commission defined 'Controls' in their report 78/316/EEC (1978) as a device that can change automotive condition or function. According to existing studies, there are many types of automotive controls; push button, touch button, multi-switch, rocker switch, toggle switch, continuous slider, discrete slider, knob, thumbwheel, stalk, lever and joystick (Kwahkand Han, 2002; Bhise, 2012). With increased in-vehicle devices and technologies, many of these automotive controls can be seen on a steering wheel considering a driver's accessibility (Park et al., 2010; Jeoung et al., 2013). In addition, controls mounted on a steering wheel are more effective than controls on the instrument panel.

Murata et al. (2009) studied on the effect of age, switch type, switch location and display information of cockpit module. In their study, young adults showed better performance result than older adults. However, when the amount of information on a display was low, the results between young and older adults were not different. In addition, type of switch and quantity of display information showed that they have an effect on operators' performance while location of switch does not. Another study showed that menu type of instrumental gauge cluster and control type of steering wheel remote control have an effect on operators' performance (Kim et al., 2011).

## 3. Design Factors of Maneuvering Complexity

To measure maneuvering complexity, collecting design factors which may have an effect on maneuvering complexity is essential. In this study, we collected some design factors through existing studies which may have an effect on maneuvering complexity.

### 3.1Number

Many existing researches suggest that 'number of controls' as a design factor which may have an effect on an operator's maneuvering task performance. There is a study on the effect of 'number of controls' mounted on a steering wheel. This study conducted an experiment with 3, 5 and 7 controls mounted on a steering wheel and the result showed longer reaction time with more controls (Murata et al., 2005). Cummings et al. (2010) also suggested 'number of displays', 'number of icons', 'number of alarms', 'number of control devices' and more as sources of interface complexity. Therefore, this study selected 'number of controls' as a design factor which may have an effect on maneuvering complexity.

### 3.2Shape

Ersal et al. (2011) used 'number of control shapes' as an objective index to measure automotive products' usability. Yun et al. (2003) used 'number of differently shaped switch' as an index to measure mobile phone properties. Therefore, this study selected 'shape of controls' as a design factor which may have an effect on maneuvering complexity.

### 3.3Type

There are many studies on 'types of controls'. An existing study demonstrated that the 'type of switch' is an important design factor (Murata et al., 2009). They conducted an experiment in their study and the result showed that integrated switch has more effect on driving performance than non-integrated switch. Another study investigated on effective IVIS menu type of the instrument gauge cluster and control type of steering wheel remote control. After conducting an experiment with a 'wheel type controller' and a '4-way directional controller', the result showed 'wheel type steering wheel remote control' was more effective with IVIS instrument gauge cluster (Kim et al., 2011). The other study also investigated on effective IVIS control type by comparing a rotary controller and a touch screen. The result showed that the touch screen is better than a rotary controller (Harvey et al., 2011). Therefore, this study selected 'type of controls' as a design factor which may have an effect on maneuvering complexity.

### 3.4Size

There are many studies demonstrating that ‘size of controls’ have an effect on maneuvering task performance. According to Fitts’ Law, an operator’s reaction time and recognition time are faster when the size of a control is large (Lambel et al., 1999). There is a study which shows an object’s size, color and brightness affect on participants performance (Steinman, 1965).

Volvo developed a guideline suggesting that the surface of a control’s inner diameter should be 10 mm, and the smaller outer surface should be 16 mm which is touched by a finger (Lundqvist and Leman, 2006). In addition, Volvo also suggested that the larger outer surface should be 20 mm which is touched by a thumb (Figure 1). Therefore, this study selected ‘size of controls’ as a design factor which may have an effect on maneuvering complexity.

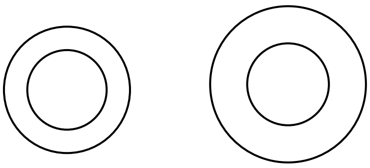

**Figure 1.**The inner and outer surface size of a control

### 3.5Location

There are many studies on location of controls. A study demonstrated that ‘location of controls’ is related to safety by analyzing time off road data when an operator performs a secondary task with 6 controls located according to degrees of visual angle ( $\alpha$ ) (Dukic et al. 2005). Lundqvist and Leman (2006) suggested that the ‘placement of controls’ as a physical demand of controls. Ford recommendation suggested that the steering wheel controls should be located between 50-105mm from the outer steering wheel rim surface and should be controlled by thumbs (Ford Recommendation, 2005). Makiguchi et al. (2003) also pointed out that ‘location of controls’ is an important factor of control design. Therefore, this study selected ‘location of controls’ as a design factor which may have an effect on maneuvering complexity.

### 3.6Gap

Gap between controls is studied by many researchers. Sawyer et al. (1996) suggested that controls should be apart from each other. Woodson et al. (1992) provided a guideline of gap between controls (Figure 2). Therefore, this study selected ‘gap between controls’ as a design factor which may have an effect on maneuvering complexity.

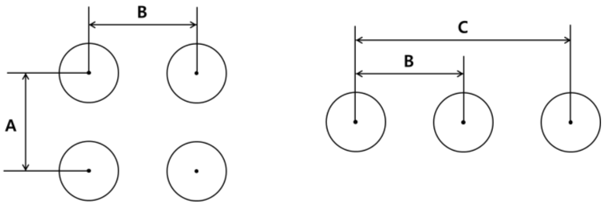


**Figure 2.**Gaps between controls

### 3.7Distance

Distance is considered as an important design factor and it is studied by many researchers. Lundqvist et al. (2006) suggested that the distance between a control and the steering wheel outer rim should be between 50-105 mm according to Ford Recommendation (2005). Fitts’ Law demonstrated that distance has an effect on performance. Therefore, this study selected ‘distance’ as a design factor which may have an effect on maneuvering complexity.

### 3.8Location Compatibility

A control should be designed based on location compatibility and when the control is designed based on it, we can expect better performance. Min et al. (2005) demonstrated that the relationship between stimulus and reaction time can have an effect on the result. This study also categorized studies on stimulus-reaction into 3 groups; spatial compatibility, movement compatibility and sense compatibility. According to this study, we can expect a better performance result when the stimulus location is more corresponds with the reaction location. Therefore, this study selected ‘location compatibility’ as a design factor which may have an effect on maneuvering complexity.

### 3.9Movement Compatibility

A control should be designed based on movement compatibility and when the control is designed based on it, we could expect better performance. Min et al. (2005) also insisted that we can expect a better performance result when the stimulus movement is more corresponds with the reaction movement. Therefore, this study selected 'movement compatibility' as a design factor which may have an effect on maneuvering complexity.

## 4. Conclusion

With the development of in-vehicle information systems, the amount of information that a driver should receive has increased. Automotive controls have increased and became complicated as in-vehicle information increased. A driver is now required to handle complicated controls and multi-tasks while driving. According to Neale et al. (2005), 78% of car crashes and 65% of near crashed are caused by a driver's inattention and inattention is caused by wireless devices, internal distractions, and passenger related secondary tasks. In this study, we examined perspectives of complexity and collected some design factors that may have an effect on maneuvering complexity through existing studies. Even though there should be more design factors that may have an effect on automotive maneuvering complexity, these design factors are proven to have an effect on the operator's maneuvering task performance through existing studies.

However, complicated driving context often require a driver to handle multi-modal interfaces, multi-tasks, and provide various devices such as a cellular phone, navigation and more. Not only complicated interfaces but also the driver's individual reasons such as gender, age, expertise, physical impediments and mental impediments are considerable factors when discussing about overall driving complexity. Environmental factors such as weather and road conditions are also considerable factors (Cantin et al., 2009). Even vehicle automation is another considerable factor. All these factors compose overall driving complexity and a method of measuring automotive driving complexity should be developed to prevent accidents caused by complicated driving context.

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