Effects of display position, secondary task and driving task difficulty on the driver's gaze behavior – A field study

Master Thesis

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Abstract

Current trends found in the automotive cockpit development, such as the engagement in additional tasks while driving including, among others, the drivers' usage of consumer electronics, and the increasing integration of in-vehicle information systems that answer the customers' needs, have a high potential of distracting the drivers. Moreover, they could force them to look away from the driving situation. In light of these potential safety critical trends, the aim of this study was to reexamine the influences of the in-vehicle display position, the secondary task difficulty and the driving task difficulty on the visual behavior of the drivers. An experimental field study was executed with 34 participants. The participants executed three tasks of different priorities: the driving task, a visual attention task and a visual secondary task with multiple difficulty levels that was presented on different displays. In this thesis, the focus was on the examination of the recorded visual behavior of the participants. The secondary task difficulty was represented by the easiest and most difficult level, the display position by the head-up display (HUD) and the instrument cluster (IC) and the driving task difficulty by two curved and two straight road sections. The results of 24 participants showed that the drivers' gaze strategies and the extents of the effects of the secondary task and driving task difficulty differed considerably depending on the display position they were looking at. The drivers executed considerably longer gazes and executed less gaze switches when focusing on the HUD compared to the IC. It was concluded that this was due to the special location of the HUD that allowed for peripheral perception according to Ecker (2013) and due to differences in the drivers' perceived levels of risk regarding the two display positions. These long gazes could, however, be potentially dangerous and should be further examined before including more information on the HUD. However, small tendencies were found that the drivers seemed to change their visual behavior in such a way that they ensured their safety and situation awareness under different circumstances. In light of the aforementioned trends this was a reassuring outcome.

Key words: visual behavior, secondary task difficulty, driving task difficulty, display position

Contents

Introduction

The driving task is described as being “a complex [and] safety-critical task” (Jamson & Merat, 2005, p. 80). Despite its inherent complexity, drivers frequently engage in additional tasks during driving, such as reading, speaking to other passengers and interacting with different technological devices (Young, Regan & Hammer, 2003). These additional or secondary tasks can have devastating consequences through distracting the drivers from their primary driving task (Victor, Harbluk & Engström, 2005; Young et al., 2003). Lee, Young and Regan (2008) defined driver distraction as “the diversion of attention away from activities critical for safe driving towards a competing activity” (pp.34). According to the National Highway Traffic Safety Administration (NHTSA, 2013), distraction has been the cause of ten percent of the deadly traffic crashes in the USA in 2011. Even when the engagement in secondary tasks and the resulting distraction and inattention do not lead to fatal consequences, secondary tasks often have negative influences on driving (Young et al., 2003). In a systematic literature review, Ferdinand and Menachemi (2014) found that “the majority of studies (80.0%) reported a statistically significant detrimental relationship between secondary tasks and driving performance” (p.42). The studies that were reviewed examined the effects of secondary tasks involving, for example, mobile phone use, smoking, and in-vehicle information systems (Ferdinand & Menachemi, 2014). Despite the mainly negative influences of secondary tasks, recent trends show that drivers engage in secondary tasks even more (Pickrell & KC, 2015). For instance, in an annual survey of the NHTSA it was found that sending text messages and interacting with handheld devices, such as mobile phones, increased considerable from 1.7 percent in year 2013 to 2.2 percent in 2014 (Pickrell & KC, 2015).

In addition to the concerned interaction of drivers with secondary tasks, another trend that has high potential of leading to more distraction and inattention, concerns the integration of increasing amounts of technology into the vehicles (Victor et al., 2005). The integration of these technologies started years ago and back then it included the involvement of “cellular telephones, more complex entertainment systems, navigation systems and other devices aimed at assisting the driver” (Chiang, Brooks & Weir, 2004, p.215). Nowadays, the trend continues and includes the incorporation of even more informative and assisting systems, the usage of innovative technologies regarding in-vehicle displays (Bengler, Götze, Pfannmüller & Zaindl, 2015) and technologies that support communication, internet usage and tasks, such as checking e-mails (World Health Organization, 2011). Even though the majority of technologies are included to support the driver, they are potentially distracting (Chiang et al.,

2004) and lead to “a growing concern over detrimental effects resulting from increased interactions with new technolog[ies] in vehicles” (Victor et al., 2005, p. 168).

Furthermore, there are potential other sources of distraction and inattention. Milicic (2009) and Ecker (2013) reported a tendency of presenting information that is not related to the driving task on displays that are near the field of view of the driver and are normally used for driving related information. This tendency includes, for example, presenting lists of radio stations or music titles in the instrument cluster (Ecker, 2013).

These discussed trends all have a potential of distracting the drivers. One aspect of these trends that needs to be considered in system design is that most of the secondary tasks, the technologies and information presented demand the driver to look away from the road (Victor et al., 2005). This aspect is especially likely to lead to harmful consequences and it is important to avoid the creation of systems that lead to high amounts of driver distraction. The aim of this thesis is to shed light on the effects of the discussed trends on the drivers’ behavior, especially their visual behavior. In the next paragraphs the literature with regard to the driving task and driving while executing secondary task with a special focus on visual secondary tasks and the visual behavior will be reviewed.

The categorization of the driving task

The driving task was described earlier as being a complex task. This complexity stems from the fact that the driving task incorporates various activities, such as observing the road (Kaber, Liang, Zhang, Rogers & Gangakhedkar, 2012), the safe guidance of the vehicle (Milicic, 2009) and checking the mirrors or the speed (Wittman et al., 2006). The different activities involved in the driving task are often described in terms of a hierarchical model, which includes three highly connected levels: the strategic, tactical and operational level (Michon, 1971; Michon, 1979). The first and highest level is the strategic level which “(…) defines the planning stage of a trip, incorporating the determination of trip goal, route and vehicle choice, and evaluation of the costs and risks involved” (Michon, 1979, pp.5-6). The second level is the tactical level, which is concerned with the circumstances at hand and therefore includes “manoeuvres such as speeding up and slowing down, turning off and overtaking (…)” (Michon, 1979, p. 6). The lowest, operational level includes the concrete actions taken to fulfill the higher level goals. These actions include, for instance, the acceleration, deceleration and the steering of the car (Michon, 1979). In addition to the inherent complexity of the driving task, drivers often enhance the complexity through engaging in additional tasks.

The driving tasks and tasks executed in addition to it are often categorized in terms of primary, secondary and tertiary or only primary and secondary tasks. An often referenced taxonomy for the former, tripartite example, is the one developed by Geiser (1985, as described by Bubb, 2015). The primary task includes the lateral and longitudinal guidance, which is achieved by means of acceleration, braking, steering and holding an appropriate distance to a leading car (Bubb, 2015). Secondary tasks are related to the driving tasks but do not have a direct influence on it. Nonetheless, these tasks are important for traffic safety and consist of, for example, indicating directions or regulating the lights of a vehicle (Bubb et al., 2015). Tertiary tasks, which include entertainment and comfort related tasks, are not related to the driving task (Bubb, 2015).

The second categorization that solely distinguishes between primary and secondary tasks is also widely used. Here, the primary task is focused on driving and related tasks, such as checking the speed and the mirrors (Wittman et al., 2006). The secondary tasks involve activities within the vehicle, such as the interaction with a mobile phone, the radio or the navigational system (Wittman et al., 2006). In the rest of this thesis, the term secondary task will be used in more general terms meaning tasks that are executed additionally to the driving task. This means that both tertiary and secondary tasks as described in the two categorizations are included in this more general term.

The categorization of the secondary tasks

Secondary tasks are also often categorized based on various aspects. One of these aspects that is often used to differentiate between secondary tasks, is focused on the modalities that the drivers use to execute a particular task (Victor et al., 2006; Rauch, 2009). This particular differentiation is of great importance, because the execution of additional tasks was found to have diverging effects on the driving performance and the visual behavior of the driver depending on the required modality (e.g., Victor et al., 2006; Rauch, 2009). With regard to driving, secondary tasks using modalities, such as vision, cognition and hearing, are often examined (e.g. Victor et al., 2006; Harbluk, Noy & Eizenman, 2002). For instance, Rydström, Grane and Bengtsson (2009) described that visual secondary tasks lead the drivers to look away from the road. Victor et al. (2005) compared the effects of visual and auditory secondary tasks on the drivers' gaze behavior and found that drivers looked less often to the road and instead looked more frequently and longer to the displays presenting the visual tasks. During auditory task execution, the gazes of the drivers where mainly focused outside on the center of the road and less on the inside of the car (Victor et al., 2005). Furthermore, Liu (2001) found that the driving performance during visual task execution was inferior to the performance during auditory and multimodal task execution regarding, for example, response time and safety. It seems thus that visual secondary tasks have a special, and potentially negative, influence on the driving performance and the visual behavior of the driver that clearly differs from tasks deploying other modalities.

The fundament of the interference between the driving task and secondary tasks. Alongside other theories and models, the multiple resource model is often used as the basis for the differentiation of secondary tasks based on the required modalities and the specific effects of visual secondary tasks on the driving performance and the gaze behavior (e.g., Horrey & Wickens, 2004; Jamson & Merat, 2005; Rauch, 2009; Kaber et al., 2012; Ecker, 2013). The model is based on the multiple resource theory, which is focused on the simultaneous execution of multiple tasks (Wickens, 2002). According to Wickens (2002), the execution of two tasks at the same time requires time-sharing. “The multiple resource model proposes that there are four important categorical and dichotomous dimensions that account for variance in time-sharing performance” (Wickens, 2002, p.163). The four dimensions include the processing stages, processing codes, perceptual modalities and visual channels and each of the dimensions has two levels (Wickens, 2002). Depending on the dimensions and the levels of dimensions that particular tasks are making use of, the time-sharing performance between the tasks can lead to a higher or lower degree of interference (Wickens, 2002). When two tasks use the same dimension or the same level of one dimension, these tasks interfere to a higher degree with each other than tasks using different dimensions or levels. The interference in turn can result in decreased performance regarding one of the tasks or both (Wickens, 2002). Based on the multiple resource model, visual secondary tasks were assumed to be especially interfering with the driving task (e.g. Horrey & Wickens, 2004; Rauch, 2009; Liu, 2001), which is also a highly visual task (Rockwell, 1971 as cited by Rauch, 2009). Through requiring the same resources the two tasks are likely to interfere which each other, which in turn increases the likelihood of performance decrements regarding the driving task or the secondary task (e.g. Jamson & Merat, 2005; Liu, 2001). So, the findings of Liu (2001) regarding the deterioration of the driving performance during more visually than auditory secondary task execution seem to be in accordance with the assumptions made in the literature.

In addition, the multiple resource model is tightly connected to the concept of attention (Wickens, 2002). Metz, Schömig and Krüger (2011) stated that during the execution of additional tasks “attention has to be divided between the primary driving task and the secondary task[, which] (…) leads to reduced attentional resources for each of the two tasks compared to performing each task alone" (p. 369). According to Kaber et al. (2012), "(…) visual attention to perceive the roadway situation (…)" is a resource that is highly important for the driving task. Horrey and Wickens (2004) stated that, "(…) two visual tasks will compete for visual attention, which often can be allocated to only one place at a time (...)" (p.611). Furthermore, time-sharing of the visual attention between the two tasks is necessary (Victor et al., 2005), which can lead to disturbance of the task execution (Horrey & Wickens, 2004). The fact that drivers redirect their (visual) attention away from the driving tasks, wherefore the (visual) attention for the driving tasks is reduced, means that the drivers are (visually) distracted because of the task (Kaber et al., 2012).

Influences of visual secondary task execution on the drivers' gaze behavior

In the previous section it became clear that secondary tasks have different effects on the driving performance and the visual behavior. Visual secondary tasks seemed to be particularly interfering with the driving task. On these grounds this thesis will be focused on visual secondary tasks and in particular on their effects on the visual behavior.

The visual behavior of drivers is often examined by means of different measures, such as the duration and the number of gazes (Victor et al., 2005). In general, the measures of the gazes to the visual secondary task and away from the road correspond to the interference or the visual demand (Ablaßmeier, Poitschke, Wallhoff, Bengler & Rigoll, 2007) and the attentional demand elicited by these tasks (Dingus, Antin, Hulse & Wierwille, 1989; Metz et al., 2011). Hence, these measures are also used to examine the time-sharing behavior that is required when two tasks make use of the same resource, such as vision and the visual attention of the driver. According to Victor et al. (2005) the time-sharing behavior is reflected in the visual behavior of the drivers "(…) with the eyes being continuously shifted back and forth between the road and the in-vehicle task" (p.169). Among others, Wierwille (1993) developed a model to explain the rationale behind these gaze switches. In this model, Wierwille (1993) described that during the execution of visual secondary tasks drivers feel an increasing need to look back at the road the longer they look at the task. On average the drivers look back at the road after a maximum of 1.6 seconds, regardless of whether the task was completed or not, because their need to look back got too strong. According to Wierwille (1993) this limit only differs slightly across individuals. Hence, if a task is not finished within 1.6 seconds, multiple gazes are directed to the task to complete it (Figure 1). This was supported by the study of Dingus et al. (1989), who found that drivers looked more often to the task instead of employing longer individual glances that exceeded the found limit of 1.66 seconds.

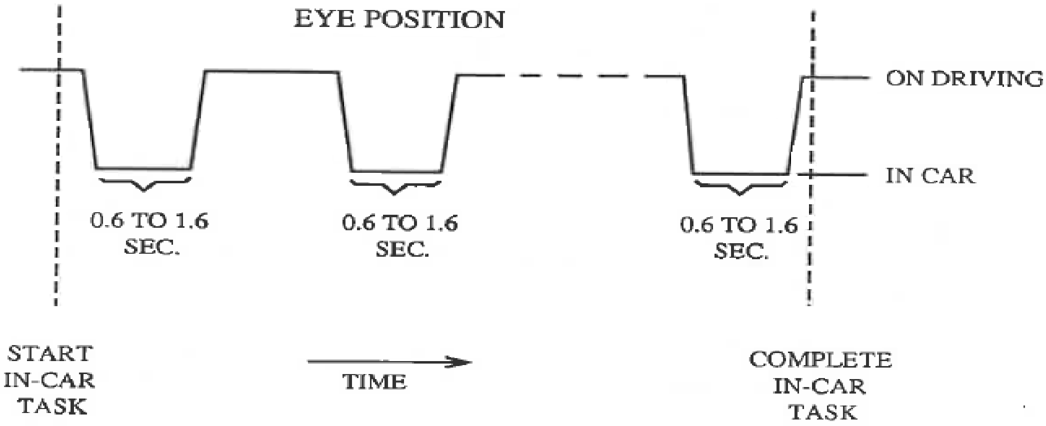

Figure 1. The in-vehicle scanning model. Adapted from Visual and manual demands of in-car controls and displays (p.304), by W.W. Wierwille, 1993. In B. Peacock & W. Karwowski (Eds.), *Automotive Ergonomics* (pp.299-320). Washington DC: Taylor & Francis. Copyright 1993 by Taylor & Francis Ltd.

However, several studies found that gazes away from the road exceeded this limit. For example, Victor et al. (2005) found that depending on the task difficulty approximately two up to 30 percent of the gazes focusing on an in-vehicle task exceeded a two second limit. In addition, Ecker (2013) found maximum gaze durations that exceeded the 1.6 limit of Wierwille by a little less than one second or even more than two seconds depending on the display the drivers were looking at. Hence, the duration of gazes focused away of the road does not always comply with the limit described by Wierwille. According to Victor et al. (2005), drivers adapt their visual behavior in terms of duration and number of gazes due to influences of different aspects. In an overview of the literature, Victor et al. (2005) and Metz et al. (2011) reviewed that these aspects entail among others the difficulty of the visual secondary task, the driving task difficulty and the position of the displays presenting the tasks. The adaption of the visual behavior due to the influences of these aspects can involve long gazes away from the road, as was found by Victor et al. (2005) and Ecker (2013). However, these long gazes can be quite problematic due to the fact that they lead to slowed reactions to or even neglecting of crucial events and less awareness of the driving situation (Boyle et al., 2013).

Agencies, such as the NHTSA, are concerned with regard to these long gazes away from the road due to their potentially dangerous consequences (e.g., NHTSA, 2013). In an attempt to reduce the amount of distraction and to increase the drivers' safety, the NHTSA and other agencies devised guidelines that include, among others, information on how long gazes to a device or a secondary task are maximally allowed to be so that the drivers are still able to safely execute the driving task (NHTSA, 2013). More precisely, according to the NHTSA (2013) the mean duration of gazes focusing away from the road should not exceed a two second limit and the total duration should not exceed twelve seconds. These guidelines should be considered, when including for example new and more technologies as is planned by automobile manufacturers.

In the next sections, the precise nature of the visual behavior adaptation due to the three reported aspects will be described.

Visual secondary task difficulty

As mentioned above, the gaze behavior of the driver during visual secondary task execution was found to be influenced by the complexity and the elicited visual demand of the secondary task (e.g., Victor et al., 2005; Dingus et al., 1989; Chiang et al., 2004). Primarily the number of gazes seemed to be influenced by the task difficulty (e.g., Victor et al., 2005; Dingus et al., 1989). In the simulator and field studies of Victor et al. (2005), it was found that the number of gazes increased by between one or almost two gazes with increasing complexity of the visual secondary task. Similar results were found in the field study of Dingus et al. (1989), as described earlier. Moreover, Metz (2009) reviewed several studies examining visual secondary tasks and the results of these studies reflected the findings above, too. The highest number of gazes to a visual task, 13.8 gazes, was elicited by the interaction with complicated infotainment technologies and the lowest number of gazes, 2.2 gazes, was focused on reading information from displays in the car (Metz, 2009). These studies were all in line with the conclusion that the number of gazes increased with rising visual secondary task difficulty. However, in one of the field studies of Victor et al. (2005) the results pointed in a different direction. Even though Victor et al. (2005) concluded for most of their studies that the number of glances to the tasks increased with increasing task difficulty, this was not true for one of the executed field studies. In that particular study, the number of gazes for the lowest difficulty level was one gaze higher than the number of gazes for the medium difficulty level. Unfortunately, Victor et al. (2005) did not elaborate on this finding.

With respect to the gaze durations, the reviewed studies were not completely in line with each other either. Regarding the individual gaze durations, the results were quite comparable. The findings of the review of Metz (2009) revealed that individual gazes endured on average 1.31 seconds during the interaction with complicated infotainment systems and 1.32 seconds for reading information from a display (Metz, 2009). Hence, individual gaze durations did not seem to differ between tasks of different difficulties. In line with that, Dingus et al. (1989) reported that drivers did not increase their individual gazes above a limit of 1.66 seconds and instead used more glances. However, while still being within the limit, tasks that were more difficult yielded significantly longer individual gaze durations than easier tasks (Dingus et al., 1989). With regard to the average and total gaze duration, Victor et al. (2005) found that with increasing task difficulty, both the total and the average gaze duration increased, too. The total gaze duration for the highest difficulty level was almost one and a half time higher than the total gaze duration for the easiest level. The average gaze duration was approximately 300 up to 400 ms higher during the most difficult tasks. Dingus et al., (1989) also found higher total gaze durations for some of the more difficult tasks.

Display positions

Another aspect that influences the gaze behavior of the drivers during visual secondary tasks is the position of the displays, where these tasks are presented (Victor et al., 2005; Hada, 1994; Ecker, 2013). Two displays that are the most common in today's cars are the instrument cluster and the multi-media interface (e.g., Hada, 1994; Ecker, 2013). In addition, a third display, the head-up display, is getting more and more attention in the literature and is getting more established in the cars, too (e.g., Broy et al., 2014, Liu, 2003). According to Milicic (2009) and Ecker (2013), the three displays and their contents correspond to the tripartite classification of the driving task of Geiser, as will be elucidated in the next sections. However, Milicic (2009) and Ecker (2013) stated that new trends showed a less strict localization of information. In the next sections, the displays will be described shortly, followed by a review of the study findings regarding the influence of display position on the drivers' gaze behavior.

The head-up display. The head-up display (HUD) commonly presents the driver with information that is critical to the primary driving task, such as information about the speed, navigation or driving assistants (Ablaßmeier et al., 2007). Recently, studies are also focusing on the question whether it is possible to present information that is not related to the primary driving task on the HUD (e.g., Milicic, 2009). Independently of the precise content, the information shown in the HUD is projected "directly into the driver's visual field" (Ablaßmeier et al., 2007, p.2251) approximately two meters ahead of the driver (Broy et al., 2014). Due to its special location and its transparent nature, the HUD allows the driver to look away from the road less often and for shorter durations (Broy et al., 2014; Liu, 2003) and the drivers can perceive the driving situation peripherally while at the same time focusing the eyes on the information presented in the HUD (Ecker, 2013).

The instrument cluster. The instrument cluster (IC) generally presents the driver with information about the driving speed, driving assistants and other status information (Ecker, 2013; Ablaßmeier et al., 2007). The information presented here, following the tripartite categorization of Geiser, belongs mostly to the primary driving task (Bengler et al., 2015; Milicic, 2009). However, also information that is related to the secondary task is presented, such as the status of the indicator of the direction or the temperature of the engine (Ecker, 2013). In most cars, the IC is localized behind the steering wheel. Therefore, the IC and the HUD differ in vertical direction. In horizontal direction, the two displays are highly comparable. Due to its position, the IC belongs to the head-down displays and hence demands the driver to look down to access information (Ablaßmeier et al., 2007).

The multi-media interface. The multi-media interface (MMI) presents the driver with tertiary information, such as information regarding entertainment, communication and navigation (Ecker, 2013; Ablaßmeier et al., 2007). The MMI also belongs to the head-down displays (Ablaßmeier et al., 2007) and is often the biggest display in the car and is localized in the middle console. The drivers have to turn their heads a little to the right and downwards to access the information.

Research findings regarding the effects of the display positions. In general, Ablaßmeier et al. (2007) reviewed that one of the HUD's advantage entails that "[t]he driver can quickly read the information near his perspective resulting in an increased eyes-on-the-road time" (p.2251). In the field study of Ablaßmeier et al. (2007), supportive results were found regarding the gaze durations. In particular, it was found that the gazes to the HUD were shorter than the gazes made to the IC and the MMI (Ablaßmeier et al., 2007). In another field study, Hada (1994) found that the drivers looked the longest to the MMI. However, the presented summary statistics showed longer gaze durations for the HUD. Due to these contradictions, the conclusions drawn by Hada should be treated with caution. With regard to the number of gazes, the results and conclusions were more coherent. It was found that drivers looked considerably less often to the HUD than to the other two displays that were looked at comparably often (Hada, 1994). In total the HUD was gazed at 3136 times, which was approximately 600 times less than the IC and MMI (Hada, 1994). In contrast to Hada (1994) and Ablaßmeier et al. (2007), Ecker (2013) reported, based on a simulator study, that the average, maximum and total gaze duration and the number of gazes were considerably higher for the HUD than for the other two displays. The average gaze duration for the HUD was on average 1.23 seconds long, which was approximately 200ms longer than for the other displays (Ecker, 2013). The maximum gaze duration was on average 4.11 seconds long, which was one up to almost two seconds higher than for the other displays (Ecker, 2013). The total gaze duration was on average 42.29 seconds long and thereby eight up to ten seconds higher than the other two displays. On average 35.62 gazes were focused on the HUD, which was four up to five gazes higher than for the other two displays. The IC and the MMI only differed considerably with regard to the maximum gaze duration, with maximum durations of one second higher for the IC than the MMI (Ecker, 2013). According to Ecker (2013) these results are in line with the special nature of the HUD that allows the driver to look at the information in the HUD while at the same time being able to perceive the driving situation. However, in the study of Ecker (2013) the task was not solely visual but included a control aspect. This could have led to the differing results and should be considered in further contemplations.

Driving task difficulty

A third aspect that was mentioned to influence the gaze behavior was the driving task difficulty or the driving demand (e.g., Victor et al., 2005; Senders, Kristofferson, Levison, Dietrich & Ward, 1967). In general, Green (2002) described that the negotiation of a curve is more demanding and critical than driving on a straight road which in turn was expected to lead to changes of the distribution of eye fixations. In their studies, Victor et al. (2005) found that the average and total gaze duration to the visual secondary tasks was considerably lower during the negotiation of a curve than when driving through a straight section. During curves the average gaze duration was one average between one and approximately 1.35 seconds, which was approximately 150 ms up to 200ms lower than during straight sections. The total gaze duration was on average around eight up to 12 seconds long, which was around 500 ms up to two seconds lower during curved sections compared to straight sections. Similar results were found by Senders et al. (1967). In their field study, Senders et al. (1967) found that drivers looked either longer or more often to the road during higher driving demands than during lower driving demands. Furthermore, Tsimhoni and Green (2001) executed a simulator study and reported that the average and total gaze duration to the visual secondary task decreased during negotiation of a curve compared to a straight road section. The average gaze duration was decreased by 600ms resulting in on average 1.2 seconds during curved road sections. Precise numbers regarding the increase of the total gaze duration were not mentioned. In addition, the number of gazes focused on the task decreased by approximately one gaze during curve negotiation resulting in around 2.6 glances, but that was only true for longer tasks (Tsimhoni & Green, 2001). In one of the studies of Hada (1994) three road types were compared, which included an expressway, a rural and a suburban road. The expressway had the highest speed limit, the most lanes, was the longest and had the highest amount of traffic (Hada, 1994). The suburban street was the shortest, had the lowest speed limit and medium traffic flow (Hada, 1994). The expressway and rural road did not differ in the mean number of gazes, but while driving on a suburban road the drivers looked less often at the displays presenting the tasks (Hada, 1994). The gaze duration differed considerably for all road types and for the expressway the average duration of gazes to the tasks was the highest. Ablaßmeier et al. (2007) compared uncritical driving situations, such as interstate roads, and more complex situations, such as situations with high amounts of traffic as can be found in cities. It was reported that drivers looked less long to the displays during more complex situations (Ablaßmeier et al., 2007).

Combined effects of the three aspects

In addition to the separate effects of the three aspects, the combined effects on the visual behavior of the drivers were examined in some of the studies. However, most of the studies did only examine the effects separately (e.g., Victor et al., 2005; Ecker, 2013). Yet, it is highly likely that the three aspects combined affect the drivers' gaze behavior differently than when they are examined alone.

In the study of Dingus et al. (1989) the main focus was on the effect of the secondary task difficulty on the visual behavior of the drivers. Nevertheless, the type of road that was differentiated in terms of the number of lanes (four versus two) was included into additional analyses. Dingus et al. (1989) concluded that the attentional demand, which was operationalized in terms of the eye movement behavior, was significantly higher when driving on the four than the two lane road. Unfortunately, the authors did not elaborate on the results in terms of changes in the number and duration of gazes made to the task or road. Hada (1994) examined the effects of the display position and the driving task on the drivers' visual behavior separately and in combination. It was reported that the drivers looked the longest to the MMI and that they looked less often to the HUD than to the other two displays that were highly comparable to each other (Hada, 1994). Moreover, on suburban streets the drivers looked the least often to all three displays (Hada, 1994). The driving task difficulty was tested here in terms of road types and it was concluded that suburban streets elicited more attentional demand than the other two road types, which in turn led to less views to the displays than when driving on the other road types (Hada, 1994).

In the study of Ablaßmeier et al. (2007) the display positions were also compared across complex and uncritical situations. It was found that the HUD yielded shorter gaze durations than the MMI and the IC in both situations. In the study of Tsimhoni and Green

(2001) the main focus was on the different road types. However, they also included the aspect of the secondary task difficulty, which was differentiated in terms of short, medium and long duration. As mentioned, Tsimhoni and Green (2001) found shorter average gaze durations during curve negotiation, but the effect was found to be more pronounced for the tasks that lasted longer. Moreover, the number of gazes only increased during curve negotiation, when the drivers were executing the longer tasks (Tsimhoni & Green, 2001).

The goal of the study

In the introduction, it was discussed that current trends are likely to distract the drivers in a way that requires them to look away, which in turn is highly likely to jeopardize the drivers' safety. The goal of this study is to reexamine the effects of the three reviewed aspects: the visual secondary tasks difficulty, the driving task difficulty and the display position by means of a field study. This re-examination is deemed important to shed light on possible problems regarding these trends, such as potential guideline inconformity. Furthermore, it could elaborate on the precise nature of the effects of the three aspects alone that were found to be quite different across the reviewed studies and in combination. Additionally, the research regarding the presentation of information on the HUD that is not driving related is not yet highly progressed and could be enriched especially by means of a field study. The focus of this thesis is on the effects of the visual secondary task difficulty and the driving task difficulty on the visual behavior of the drivers with regard to different display positions in the vehicle. With respect to the display position, the focus is on the HUD and the IC. The main research question is as follows: '*How do the visual secondary task difficulty and the driving task difficulty influence the drivers' visual behavior with regard to different display positions in the vehicle?'*. The main research question is split up into two sub-questions. Per sub-question it will be examined how the addressed aspects influence the drivers' visual behavior concerning the displays in terms of number and duration of the gazes.

The first sub-question is focused on the visual secondary task difficulty: '*How does the visual secondary task difficulty influence the drivers' visual behavior with regard to different display positions in the vehicle?'*. The majority of studies reported higher average and total gaze durations and higher number of gazes for more difficult tasks. This lays the basis for hypothesis 1.1. Here, a normed version of the total gaze duration will be used, which examines the percentage of gazes to a particular display, for instance the HUD. It will be called gaze percentage. In addition, instead of the number of gazes the number of gaze switches from a certain display to another or to the surroundings and back will be used. It is assumed that the effects of the different aspects are comparable for the two types of measures.

Furthermore, most studies reported no considerable changes regarding the individual gaze durations with changes in the secondary task difficulty. Here, the focus is on the maximum gaze duration only and it is hypothesized that it does not increase either (hypothesis 1.2). With respect to the display positions, most of the studies reported shorter durations of gazes to the HUD than to the other displays. However, Ecker (2013) argued and found that longer gazes would be directed to the HUD than to the other displays due to the fact that the presented information is visually closer to the road, which can still be perceived peripherally while looking at the HUD. In this study, the argumentation of Ecker (2013) will be followed. Hence, it is hypothesized that gazes to the HUD are longer and the gaze percentage is higher for it than for the IC. Furthermore, Ecker (2013) found a higher number of gazes towards the HUD than the other displays. It is assumed that for both easy and difficult tasks, the HUD yields the highest gaze duration and number of gaze switches, which leads to hypothesis 1.3 and 1.4.

Hypothesis 1.1: *The gaze percentage, the average gaze duration and the number of gaze switches are higher for a difficult secondary task than for an easy secondary task.*

Hypothesis 1.2: *The maximum gaze duration is not higher for a difficult secondary task than for an easy secondary task.*

Hypothesis 1.3: *For an easy secondary task, the number of gaze switches, the gaze percentage and the maximum and average duration of gazes focused on the HUD are higher than for the IC.*

Hypothesis 1.4: *For a difficult task, the number of gaze switches, the gaze percentage and the maximum and average duration of gazes focused on the HUD are higher than for the IC.*

The second sub-question is focused on the driving task difficulty: '*How does the driving task difficulty influence the drivers' visual behavior with regard to different display positions in the vehicle?*'. The reviewed studies reported that depending on the driving task difficulty, the visual behavior of the drivers changed. It was found that the average and total gaze duration focusing on a task, was lower during more difficult driving tasks than during more easy driving tasks (e.g., Victor et al., 2005). For the maximum gaze duration there were no results discussed in the reviewed literature. Nevertheless, it is hypothesized that the maximum gaze duration would also decrease during more difficult driving tasks. This forms the basis of hypothesis 2.1. Moreover, significant or tendential increases of the number of gazes towards a task were found during curve negotiation in comparison to driving on straight sections. These results are the basis for hypothesis 2.2. Furthermore, based on the argumentation of Ecker (2013), it is assumed that the mean and average gaze duration and the gaze percentage for the HUD are higher than for the IC for both easy and difficult driving tasks. In addition, it will be assumed that drivers look more often to the HUD than the IC for both driving difficulties due to the special location of the HUD. This lays the basis for hypothesis 2.3 and 2.4.

Hypothesis 2.1: *The average and maximum gaze durations and the gaze percentage are lower during a difficult driving task than during an easy driving task.*

Hypothesis 2.2: *The number of gaze switches is higher during a difficult driving task than during an easy driving task.*

Hypothesis 2.3: *For an easy driving task, the number of gaze switches, the gaze percentage and the maximum and average duration of gazes focused on the HUD are higher than for the IC.*

Hypothesis 2.4: *For a difficult driving task, the number of gaze switches, the gaze percentage and the maximum and average duration of gazes focused on the HUD are higher than for the IC.*

In addition, according to the model of Wierwille the average gaze duration and the maximum gaze duration should not exceed the limit of 1.6 seconds. Following Wierwille (1993) this should be true for the different secondary task and driving task difficulties. This will be examined by means of an additional hypothesis.

Hypothesis 3.1: *On average, the maximum and average gaze duration do not exceed the 1.6 seconds limit.*

Method

An extensive field study was executed as part of a series of studies that were or will be executed by Sandbrink (in preparation) at the research and development department of the Volkswagen AG as part of achieving the PhD title. One aspect of this study comprised the recording of the drivers' visual behavior. This built the basis to answer the research question of this study regarding the effects of the visual secondary task and driving task difficulty on the visual behavior of the drivers concerning the HUD and IC. Other aspects of the executed study, such as the driving performance or self-report measures are not the focus of this study and are therefore only described shortly. For more information regarding these aspects see Sandbrink (in preparation).

Participants

It was planned to achieve a sample size of at least n = 30 participants, with an even distribution regarding the gender, age and driving experience of the participants. The participants were recruited by the participant pool of the Volkswagen AG. The recruitment of the participants was subject to several requirements, which included being a Volkswagen AG employee so that the nondisclosure regarding the goal and content of the study was ensured, having a driver's license, being German and not wearing glasses. For their participation, the participants received a gift that was provided by the participant pool.

In total, n = 34 participants took part. However, four participants were removed from the sample due to technical problems leading to complete data loss or to incomparable experimental conditions, or because the language requirement was not met. Furthermore, six participants were removed because the eye tracking was observed by the research leader to be less than optimal. Eventually, the sample included n = 24 participants, of which n_f = 11 participants were female and n_m = 13 were male. The age of the sample ranged from 19 to 51 years with a mean age of 33.13 years (SD = 8.81). The participants owned their driver's license on average 15.58 years (SD = 8.51) and more than 85% drove up to 30.000km per year. Furthermore, n = 11 (46%) participants had no prior experience with the HUD and n = 13 (54%) participants had only little to moderate experience with it.

Apparatus

Eye tracking system. The participants' gaze behavior during the experimental tasks was assessed by means of the eye tracking system faceLAB^{TM} 5 of Seeing Machines (2012). This system was chosen among others because it is non-invasive (Seeing Machines, 2012). Due to the length of the experimental sessions, the unobtrusiveness of the system was a requirement to prevent discomfort. In addition, this system did not make use of video recordings. This was of importance due to the fact that video or photo recordings were not allowed on the research area of the Volkswagen AG in Ehra.

This eye tracking system makes use of two cameras and an infra-red pod that shines infra-red light into the eyes of the participants (Seeing Machines, 2012). The reflection of the infra-red light is the basis for the images that are gathered by the two cameras, which are in turn the basis for tracking, among others, the eyes of a person (Seeing Machines, 2012). Based on a pre-defined world model in which objects of interest are defined, the faceLAB^{TM} software can compute when and for how long a given person is looking at a specific object (Seeing Machines, 2012). The system records eye gaze data at a rate of 60Hz.

In this study, the two cameras and the infra-red pod were mounted onto the dashboard of the test vehicle in front of the driver (Figure 2). A world model was defined incorporating

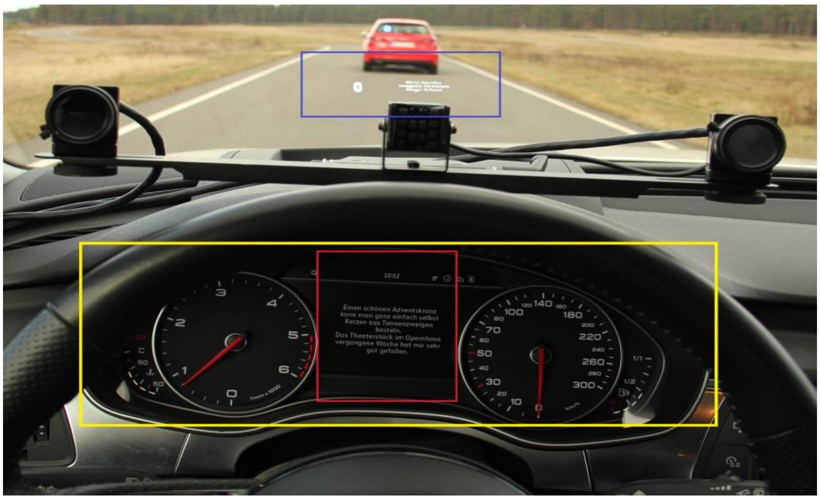

Figure 2. The two target displays HUD (blue outlined) and IC (yellow outlined) and the faceLAB™ eye tracking system.

the three displays: the HUD, the IC and the MMI. In addition, the surroundings that entailed the road and the interior of the car were included in the world model. In their literature review, Sharafi, Soh and Guéhéneuc (2015) reported that the faceLAB™ eye tracker had a visual accuracy of 0.5° under ideal conditions. Hence, directly after the system was calibrated. These ideal conditions were not met at all times, due to the fact that an experimental session lasted three hours. Even though the system was recalibrated for each display and was checked repeatedly, the duration of a session and the movement of the participant during driving were not per se ideal conditions. To deal with these circumstances, the size of the displays, with exception of the HUD, was measured and then fifteen percent of the size was added onto the actual size in the world model. It was assumed that no information that would be of high interest or thoroughly observed by the participants during the study in the real world would be included in the added fifteen percent. The size of the HUD projection (Figure 2, blue border) on the windshield was approximated. The size of the IC (Figure 2, yellow border) was measured excluding the rev counter and the tachometer (Figure 2, red border). Table 1 in Appendix A shows the actual or approximated size of the displays and the adjusted size used in the world model. Due to the fact that only two decimal places could be entered, the adjusted size was rounded up to the next full number.

Instrumental cars. In this study, two cars were used. One test vehicle in which the participants were driving with the described instrumentations and a second, rabbit car, which was driven by a professional driver of the Volkswagen AG.

Test vehicle. The test vehicle was a white Audi A6 with an automatic transmission. This car included a serial windshield HUD and it was already reconstructed in a way that

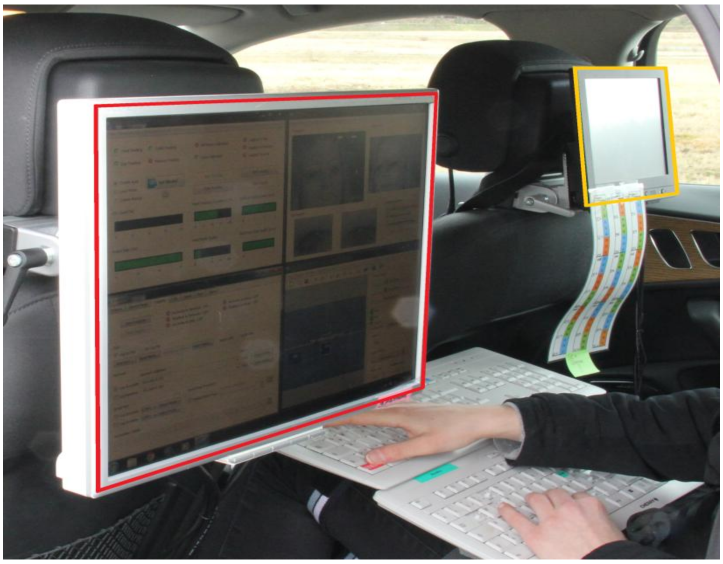

Figure 3. The Experiment configuration in the back seat of the test vehicle.

allowed overriding the serial contents of the HUD, the IC and the MMI with any content needed. In addition, multiple computers were installed that were used for the eye tracking system, for recording the CAN signals, such as vehicle speed or breaking pressure, and for running the software that presented the visual secondary tasks to the participants.

Furthermore, as described earlier, the cameras and the infra-red pod of the faceLAB™ eye tracking system were installed on the dashboard in front of the driver. In the back of the car, two screens were attached to the headrests of the driver and the front-seat passenger. The screen behind the driver was connected to the computer for the eye tracking system and the computer that executed the ADTF (Automotive Data and Time-Triggered Framework) software environment of the AUDI Electronics Venture GmbH, which was used to record the CAN (Controller Area Network) signals including, for example, signals from the engine or the transmission (Figure 3, red outlined). The screen behind the passenger was connected to the computer that was running the program for the visual secondary tasks (Figure 3, yellow outlined).

Rabbit car. The rabbit car was a red Audi A3 with automatic transmission. The car was equipped with a CAN recording system, too. Moreover, a blue LED lamp was installed in the back of the headrest of the left back seat. This lamp was used for a visual attention task. The lamp was controlled by a raspberry pi computer, which was set up on the passenger seat together with a keyboard, so that the driver could control it and start the task for each round.

Driving environment

The field study took part on the handling course of the Volkswagen research area in

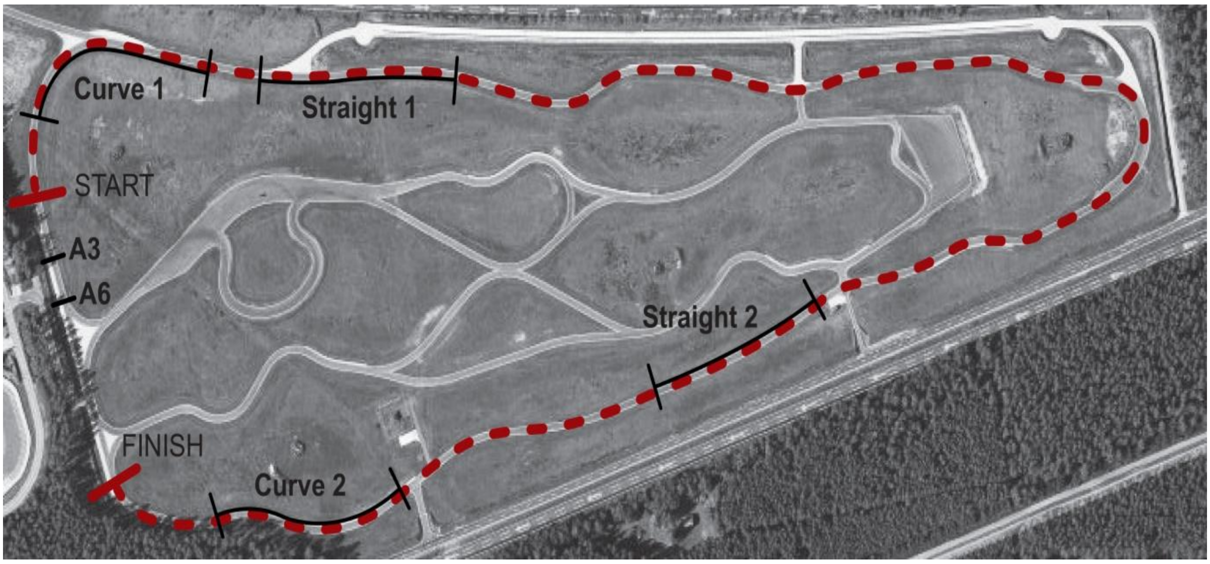

Figure 4. The handlings course of the Volkswagen research area in Ehra.

Ehra. For this study, the outer route of the handling course (Figure 4, red dashed line) was chosen and the starting point for the rounds was set right before the first curve of the handling course (Start, Figure 4). The ending point was set right after the last curve (Finish, Figure 4). Each round was approximately 2.8 km long. In the straight section between the ending and starting point, two points marked where the rabbit car (A3, Figure 4) and the test vehicle (A6, Figure 4) had to be parked at the beginning of each round. At this point, the participants were instructed on the new tasks and could take a break etcetera. No further vehicles were on the course during the experiment.

Tasks

During the study, the participants were asked to execute three tasks with different priorities, which will be explained in the following sections.

Driving task. The primary priority task was the driving task. The participants were asked to follow the rabbit car in an equal distance, which the participants deemed comfortable for themselves. Furthermore, they were asked to drive in the middle of the lane and not to cut the curves. The rabbit car driver was instructed to drive at a maximum speed of 60 km/h, to drive in the middle of the lane and not to cut the curves either. In addition, in foresight of a curve, the driver stopped accelerating and let the car decelerate on its own instead of braking. The rabbit car driver always drove in a highly constant manner.

Visual attention task. The next task, which was the second priority, was a visual attention task. The participants were asked to say "blue" as quickly as possible every time the blue LED lamp in the rabbit car gave a signal. The signal burned for approximately one second each time and throughout the rounds it burned irregularly for four times. This task was a modified version of the peripheral detection task of Van Winsum, Martens and Herland (1999), which is "used to measure workload while driving" (p.17). In the original task, "a small red square was presented during one second on the simulator projection screen in the visual periphery of the subject. Subjects were required to respond to the appearance of the red square as quickly as possible (…)" (p.17). However, in this study the goal was to examine whether the participants were still able to peripherally perceive and react to their environment and stimuli outside of the car during the visual secondary task execution. Therefore, the task was modified what included the placement of the blue LED lamp in the rabbit car. During visual secondary task execution, thus, when the participants were looking at the displays, the LED lamp was situated in their visual periphery.

Visual secondary tasks. The third task, which was of the lowest priority, included the execution of a visual secondary task. Due to the low priority, the participants were instructed to execute these secondary tasks only when they had capacities left, while simultaneously driving and executing the visual attention task. Three visual secondary tasks were designed based on the literature. All tasks were visual search tasks and included the task to count a certain aspect of the shown content, as specified in the next paragraphs. Based on a pre-study executed by Sandbrink (in preparation), three task types of varying difficulty levels were chosen. The focus here is on only the most easy and most difficult level. Therefore, only these two levels will be described in detail.

Texts. The first visual secondary task type entailed sentences varying in length. The participants were asked to count the sentences that were wrong. A sentence was wrong, when a word was included that disturbed the syntax of the sentence, even though the word was related to the meaning of the sentence. For example, "Today it snowed clouds again." would have been a wrong sentence, because the word *clouds* disturbed the syntax despite the fact that it fitted regarding the context. This task was based on the Stolperwörter-Lesetest (stumble words reading test) of Metze (2007), which is used to test the reading skills of children in classes one to four.

The easiest level (Figure 5A) included one sentence with a minimum of 20 and a maximum of 40 characters. The answer could have been zero for a right sentence and one for a wrong sentence. The most difficult level (Figure 5B) included one long sentence and a short one or two medium long sentences, with a minimum of 120 and a maximum of 140 tokens. Answer possibilities have been zero, one, two or three.

Lists. The second visual secondary task type included lists of names. The lists entailed both first and surnames and the task was to count the female first names. This task was based

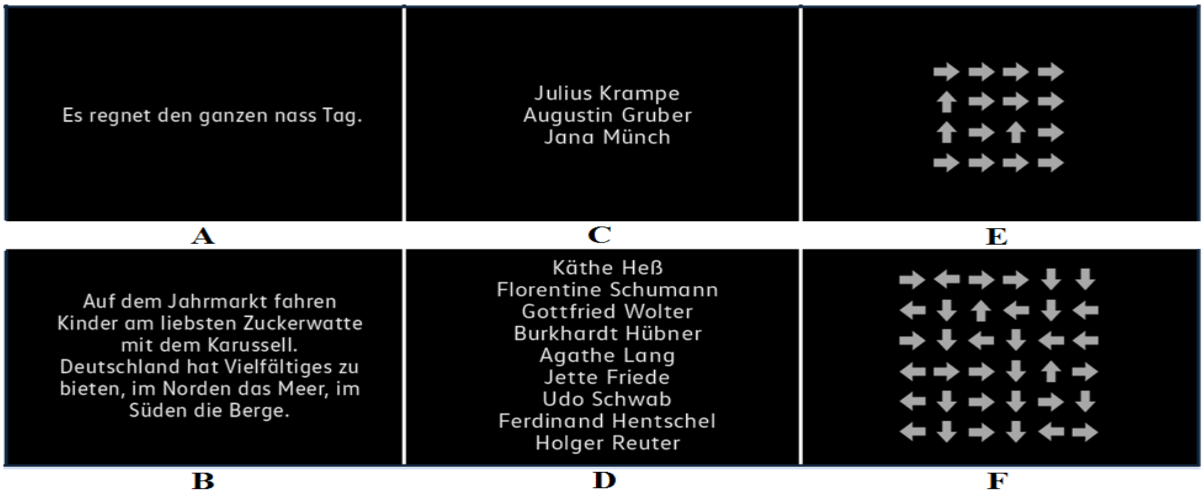

Figure 5. The three Types and two Difficulty Levels of the Visual Secondary Tasks. The visual secondary task types from the left to the right: Texts, Lists and Pictures. The first row shows the easy and the second row shows the difficult difficulty level.

on a task used by Tsimhoni, Green and Watanabe (2001), who asked their participants to identify whether a shown prename was female or male. In this study, the task was modified in order to match the other visual secondary tasks' complexities and to be representative for information presented in the car context, such as contact lists in the telephone app or navigation system.

The easiest level included three entries (Figure 5C) and zero to three female names could be found in this level. The most difficult level had nine entries (Figure 5D), with a minimum of two and a maximum of seven female names.

Pictures. The third visual secondary task included pictures showing arrows pointing in different directions. The task entailed to search for the arrows that were pointing upwards and to count these. This task was a modified version of the visual secondary task used in the HASTE Project (Roskam et al., 2002). In their studies, Roskam et al. (2002) asked the participants to solely identify whether an upward facing arrow was present or absent. In this study, the task was modified in order to be comparable to the other secondary tasks regarding the counting aspect and regarding the time needed to execute it. In general, the picture task was included in order to represent the interaction with graphical representations that are shown in the car, such as navigational maps.

The easiest level of the picture task (Figure 5E) entailed sixteen arrows pointing in two possible directions, upwards and to the right. The difficult level included 36 arrows pointing in four possible directions (Figure 5F). For every difficulty level, a minimum of one and a maximum of six upwards pointing arrows could be found.

Measures

Performance measures. The performance measures included the eye tracking data, the recordings of the driving performance of the participants and the professional driver and the participants' visual attention and their visual secondary task performance.

Eye tracking. The faceLAB™ software recorded various aspects of the participants' gaze behavior, such as where the participants were looking in form of pixel coordinates, world coordinates and when the participants closed their eyes or executed a saccade.

Driving performance. Different CAN signals, such as the vehicle speed, braking pressure and the steering wheel angle were recorded in both vehicles and can be used in order to analyze the driving performance, such as the distance that the participants maintained to the rabbit car.

Visual attention task performance. Each time the participants recognized the signal of the lamp and said blue it was annotated, resulting in the number of correctly identified lamp signals.

Visual secondary task performance. The participants' answers regarding the visual secondary tasks were written down. Per participant, the number of executed task items, the answers per task and the correctness of the answers can be used for further analyses.

Self-report measures. In addition to the performance measures, three self-report measures were included.

Questionnaires. Two questionnaires were designed for this study, one focusing on personal details and the other one focusing on smartphone usage.

Questionnaire regarding personal details. The first questionnaire was focused on the socio-demographic characteristics of the participants, such as their age and gender, and on their personality. Multiple established personality questionnaires or scales were included. These will not be described in more detail here, because the results of these questionnaires will not be included in further analyses. The questions that were of importance for this thesis can be found in Appendix B.

Questionnaire regarding smartphone usage. The second questionnaire was focused on the participants' smart phone usage in general and during driving. The questionnaire will not be described in detail either, because the results are also excluded from further analyses.

Scales for subjective effort. In addition, a scale was included in order to measure the subjective experienced effort while executing the visual secondary tasks during driving. This scale was the German version of the Rating Scale Mental Effort (RSME) of Zijlstra (1993), the Skala zur Erfassung subjektiv erlebter Anstrengung (SEA), which was validated by Eilers, Nachreiner and Hänecke (1998).

Research Design

In the executed study, a 3x3x3 factorial design was used with only within-subjects effects, which included the three displays, visual secondary tasks and difficulty levels of the tasks. Each participant had to execute each of the three tasks with each of the three difficulty levels on each of the three displays. Per task, the participants were presented with different items. The three displays, tasks and difficulty levels were the independent variables. Their influence on the dependent variables, including the gaze behavior, the driving performance, the visual attention task execution, the visual secondary task execution and the subjective measures were examined. In this thesis, only two displays and two difficulty levels and their effects on the visual behavior are examined.

To minimize possible learning and positioning effects, the order of the displays and the order in which the tasks and the task levels had to be executed per display were randomized (Sedlmeier & Renkewitz, 2013). Three groups were formed and the participants were evenly distributed over the groups.

Procedure

In the early stages of the study execution, the time slots for the first six participants were scheduled for two and a half hours. However, these slots were too short to execute every part of the study. Therefore, further slots were extended to three hours.

Firstly, the research leader introduced the participants to the study purpose and the content. Afterwards, a second research leader started the first part of the faceLAB™ calibration. For the calibration, several, differently angled pictures were taken of the participants' faces. Once the pictures were taken, the participants filled out the first part of the questionnaire. Simultaneously, the second research leader used the pictures to digitally set markers on the eyes, the mouth and other important facial characteristics of the participants to enable the software to recognize these aspects and, hence, to enable the program to compute where the participants were looking. After completion of the first questionnaire, the faceLAB™ calibration was continued. This included the camera calibration and the adjusting of the world model to every participant. For the last part, the participants had to look at the three displays enabling the software to place them at the right distance and angle in relation to the participants. This ensured that the gazes to the three displays were recognized and recorded as such by the software.

Subsequently, the first research leader explained the three tasks and their priorities to the participants. In order to explain the visual secondary tasks properly and to allow the participants to practice the tasks with feedback, the tasks were explained on the MMI. The participants were instructed that they controlled the pace in which they were executing these tasks. Only when they gave an answer, a new task item would be presented to them and they could continue with the task when they had enough capacities. Before a round started, the participants were already presented with the new task and an example task item. When the participants passed the starting point, a new task item was presented to them and they could start executing the task. When the ending point was passed, the round and the task execution stopped. Simultaneously to the instructions, the second research leader started the recordings of faceLAB^{TM} and the ADTF. When everything was prepared and the participants and the research leaders were ready, two practice rounds were driven in order to familiarize the participants with the car, the route and the visual detection task. During the practice rounds, the participants were asked to drive as was explained to them and to execute the visual attention tasks. After each round the participants stopped at the marked parking point. When the participants felt familiarized with the route, a first baseline ride was recorded that included the same tasks for the participants as the practice rounds. Afterwards, the participants were asked to mark the SEA scale.

After the first baseline, the main part of the study started, which included the execution of the three visual secondary tasks on the three displays. Per display, nine rounds were driven. For each task type the participants drove one round per difficulty level. During the whole experiment, the second research leader annotated the start and end time of each round and the participants' reaction to the LED signal through faceLAB^{TM} and controlled the program that presented the participants with new items.

When the participants finished one task type they were asked to fill out the SEA scale. They were asked to mark both scales with one cross for each round they drove, thus one cross for each difficulty level. This procedure was followed for all tasks and for all displays. When the nine rounds for one display were completed, the second research leader stopped the faceLAB^{TM} recording and reexamined the world model settings by letting the participants look at the three displays again. This was done to ensure the correct placement of the displays in the model during the whole study. Afterwards, a new recording was started for the following display.

After all the tasks were executed on the three displays, another baseline ride was recorded followed by marking the SEA scale. Afterwards, the participants were asked to fill out the second questionnaire and after completing it, the participants received a gift and the study was completed. A short overview of the procedure can be found in Table 2 (Appendix C).

Data preparation

In order to extract the gazes from the raw data and to compute the needed gaze measures for the data analysis a multitude of steps were taken to prepare and clean the raw data from measurement errors as thoroughly as possible. Errors that were removed included, for instance, cases in which only one frame was focused on a certain target. The executed steps were mainly taken by means of the statistical program R.

Moreover, four road sections of 150m length were extracted from the data per round. These sections are the basis for the comparison of the gaze behavior during diverging driving task difficulties. The difficulty of the driving task and hence the four sections were chosen based on the measures of the lateral and longitudinal guidance of the vehicle, which included the speed and the amplitude of the steering wheel angle. Two straight sections and two curved sections were chosen (see Figure 4, page 22). As can be seen in Table 3, these two road section types differed considerably regarding the changes in the averaged amplitude of the steering wheel angle and the averaged speed. The straight road sections yielded only slight changes in the averaged steering wheel angle amplitude, which ranged from .00 to 10.17 degrees (Table 3). In conjunction with these lower changes in amplitude, the drivers were able to achieve a higher average speed (M = 59.34 km/h, SD = 3.09 km/h). The curved road sections by contrast yielded substantial changes in the amplitude, which ranged from .01 to 65.22 degrees, and in turn permitted only a lower average speed (M = 45.57 km/h, SD = 2.84 km/h). Based on these considerable changes in the average steering wheel angle and the lower average speed that could be driven, the curved road sections were chosen to represent higher driving task difficulties, whereas the straight road sections were chosen to represent lower difficulties.

Per section, the average and maximum gaze duration, the gaze percentage and the number of gaze switches to and away from a certain display were computed. Table 4 provides the definitions of the gaze measures as used in this study. Per section, the four measures were computed for each display and the surroundings. For the computation of the average gaze duration only gazes that started and ended in a section, thus only complete gazes were considered. Incomplete gazes that did not start and end during a section and gazes that started before, endured the whole section and ended after it were excluded. The rationale behind this

Table 3

Overview of the averaged steering wheel angle amplitude and vehicle speed for the two road section types.

	Speed (in km/h)				Steering Wheel Angle Amplitude (in Degrees)			
	M	*SD*	*Min*	*Max*	*M*	*SD*	*Min*	*Max*
Overall	52.48	7.50	32.77	72.00	18.54	13.88	.00	65.22
Curves	45.57	2.84	32.77	59.99	31.51	6.85	.01	65.22
Straights	59.34	3.09	42.59	64.99	5.68	2.91	.00	10.17

Note. The average steering wheel angle amplitude is presented in absolute values.

Table 4.

Definition of the gaze measures.

	Definition
Gaze Duration	The duration of a gaze was defined as the time from the first frame of a gaze fixating a certain display until the last frame of the same gaze fixating it. Including any moving fixations on the same display, but excluding the movement to and away from the display.
Average Gaze Duration	The average of the duration of all gazes within a certain road section.
Maximum Gaze Duration	The longest gaze duration to a certain display per road section.
Gaze Percentage	The normed version of the total gaze duration. Per road section, the aggregated gaze duration of all displays combined and per display was computed. The latter was divided by the former and the result was multiplied with 100.
Number of Gaze Switches	The total number of gaze switches to a certain display and away from it to any other display or to the surroundings.

decision was that these incomplete gazes were highly likely to distort the average gaze duration and therefore also likely to distort the results and conclusions drawn from them.

Furthermore, in the theory section it was mentioned that a standardized version of the total gaze duration, the gaze percentage, would be used. This measure takes into account that the participants drove through a certain road section at different velocities. Therefore, the participants completed a road section in varying durations leading to different total gaze durations and in turn decreasing the comparability of this measure in its usual form.

The data of all participants were included into one dataset. The exercise and baseline rounds, the rounds including the MMI as target display and the rounds with the medium difficulty level of the visual secondary task were removed. Thus, per participant twelve rounds were examined. With four road sections per round, which resulted in 48 road sections or observations per participant. However, all cases of more than 20 gaze switches executed during a road section were removed from the final dataset (n = 13), because these cases were likely to originate from unstable eye tracking. Furthermore, all cases in which nothing was recorded were removed from the dataset, too (n = 24).

As a last step four target display variables were created, one for each of the four gaze measures. As mentioned above, the four gaze measures were computed for all displays and the surroundings for each road section. The target display variables included only the values of the corresponding gaze measure for the respective target display on which the visual secondary task was executed.

Data analysis

Firstly, an explorative data analysis was executed. During this analysis it was examined whether the data fulfilled the requirements of homogeneity of variance, normal distribution and whether outliers were included. The requirements were sufficiently met. See Appendix D for the syntax and scripts of the steps taken and more detailed results. Moreover, the means and standard deviations were computed for the dependent target display variables with additional frequency tables for the average and maximum gaze duration including the 87.5th percentile in order to check for the compliance to the NHTSA guidelines. The 87.5th percentile is based on the criteria of the NHTSA (2013). These describe that the duration of the gazes away from the road during secondary task execution should be below the two seconds limit for at least 21 out of 24 participants, which is equal to 87.5 percent.

In the next step, the hypotheses were tested. A linear mixed effects (LME) model was used in order to deal with the repeated measures that were executed per participant, display, secondary task difficulty and per road section. The participants were included in this model as a random effect and the display, the secondary task difficulty and the road section were included as fixed effects. The four target display variables were included in the model as dependent variables. Hence, only the gaze behavior regarding the target displays was examined. With regard to the number of gaze switches a LME model based on the Poisson distribution with an additional observation level random effect was executed in order to take possible overdispersion of the data into account. For all models, all main- and interaction-effects were computed for the fixed and random effects.

Results

In the following sections the results of the different analyses will be discussed.

Explorative Data Analysis

As discussed, the data met the requirements sufficiently. Furthermore, the data was checked for outliers. Extreme values were found for all dependent target display variables that could be described as outliers. However, these extreme values were not removed due to the fact that these values are highly likely to reflect natural behavior of the drivers. For a more detailed overview of the explorative data analysis see Appendix D.

Descriptive Analysis

The tables presenting the descriptive statistics for the four dependent variables can be found in Appendix E. The scripts, more detailed results and the syntax of all executed analyses are presented in Appendix F.

Table 5 shows the 87.5th percentile for the average and the maximum gaze duration. It can be seen that the 87.5th percentile of the average gaze duration for the HUD, difficult sec-

Table 5

The 87.5th percentile for the Average and Maximum Gaze Duration

	Average Gaze Duration (in ms)		Maximum Gaze Duration (in ms)	
		Percentile		Percentile
	N	87.5 %	N	87.5%
Total	986	1998.91	1039	4444.00
Display Position				
HUD	477	2646.83	525	6343.75
IC	509	1490.63	514	2559.00
Secondary Task Difficulty				
Easy	496	1899.13	514	3925.63
Difficult	490	2270.38	525	5605.50
Road Section				
Curves	501	1908.64	516	4411.63
Straights	485	2122.00	523	5207.50

ondary tasks and straight road sections was above the two seconds limit. However, the 87.5th percentile of the IC, the easy secondary tasks and the curved road sections regarding the average gaze duration were below the limit. Regarding the maximum gaze duration, the 87.5th percentile exceeded the two seconds limit for all displays, difficulty levels and road sections.

Results of the Linear Mixed Effects Models

In the following sections, the results of the linear mixed effects models with the four dependent variables will be discussed and are then brought into context with the hypotheses.[1]

Maximum Gaze Duration. Table 6 shows the results of the LME model with the maximum gaze duration (MGD) as dependent variable. The intercept of the model represents the MGD for the target display IC during easy secondary tasks and curved road sections. As can be seen in Table 6, there was a great effect of the display position (M = 1275.43, SD = 226.41, 95% CI [830.38, 1706.58]). Provided that participants drove through curved road sections and executed easy secondary tasks, the estimated mean of the MGD of the HUD as target display (M_{HUD} = 2627.83) was almost twice as high as the estimated mean of the MGD when the IC was the target display. However, there was a considerable variation in the effect of the HUD due to individual differences of the participants (SD_{RE} = 722.45), as shown by the random effects.

As can be seen in Table 6, there was only a very small effect of the road section. In contrast, the effect of the interaction between the display position and the road section was of considerable size (M = 899.46, SD = 272.14, 95% CI [358.12, 1422.95]). As can be seen in Figure 6, provided that the IC was the target display and an easy secondary task was executed there was no considerable difference of the MGD between curved (M_{IC_Curves} = 1352.40) and straight road sections ($M_{IC\_Straights}$ = 1392.04). As opposed to this, the estimated mean of the MGD of the HUD as target display when executing easy secondary tasks, was almost one second higher when driving on straight road sections ($M_{HUD\_Straights}$ = 3566.93) than curved road sections (M_{HUD_Curves} = 2627.83). Hence, only through the interaction with the HUD display the road section seemed to have a considerable influence on the MGD. However, there was quite a high variation of approximately half a second due to individual differences (SD_{RE} = 551.24).

Furthermore, there was only a small effect of the secondary task difficulty as shown in

[1] For a general discussion about the new practices with regard to reporting results without p values, see Cumming (2014). Moreover, for more explicit explanations regarding the interpretation of the results of linear regressions and linear mixed effects models see Gelman and Hill (2007), for example chapter three.

Table 6

Results of the LME Model with the dependent variable Maximum Gaze Duration (in ms)

	Fixed Effects				Random Effects
			Credibility Interval (95%)		
	M	*SD*	*Lower Bound*	*Upper Bound*	*SD*
Intercept [IC/ Easy Secondary Task/ Curved Road Section]	1352.40	153.13	1043.06	1640.61	477.78
Display Position	1275.43	226.41	830.38	1706.58	722.45
Road Section	39.64	173.39	-295.99	381.37	168.74
Secondary Task Difficulty	360.25	197.34	-24.42	746.89	436.15
Display Position x Road Section	899.46	272.14	358.12	1422.95	551.24
Display Position x Secondary Task Difficulty	891.80	253.74	395.15	1394.82	356.81
Road Section x Secondary Task Difficulty	16.13	239.75	-448.94	496.87	116.95
Display Position x Road Section x Secondary Task Difficulty	-339.36	337.96	-1019.80	326.02	154.36
Residual					1315.34

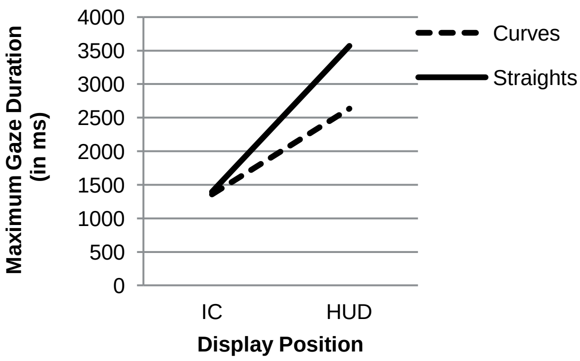

Figure 6. Interaction between the Display Position and the Road Section.

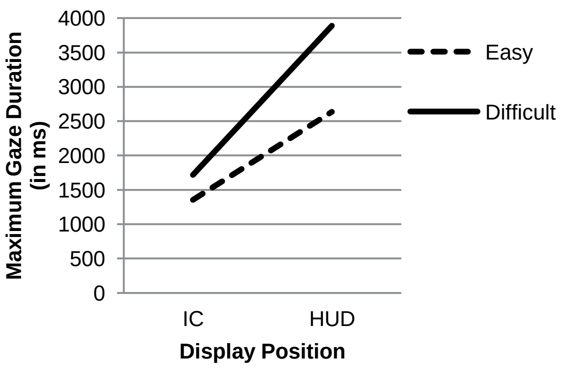

Figure 7. Interaction between the Display Position and the Secondary Task Difficulty.

Table 6. Provided that the IC was the target display and driving on a curved road section, the estimated mean of the MGD to the IC only slightly increased during difficult secondary tasks ($M_{IC\_Difficult}$ = 1712.65) compared to easy tasks (M_{IC_Easy} = 1352.40). Here, the variation due to individual differences was also very high (SD_{RE} = 436.15) considering the estimated increase of only 360.25ms. In contrast, there was a sizeable effect of the interaction between the secondary task difficulty and the display position (*M* = 891.80, *SD* = 253.74, 95% CI [393.95, 1394.82]). The estimated mean of the MGD to the HUD as target display increased by more than one second when executing a difficult secondary task ($M_{HUD\_Difficult}$ = 3879.88) compared to an easy task (M_{HUD_Easy} = 2627.83). Thus, the influence of the secondary task difficulty on the MGD was only considerable in interaction with the HUD (Figure 6). Figure 6 and Figure 7 both show the discussed effect of the display position for both different secondary task difficulties and different road sections.

Moreover, there was only a very small and therefore negligible interaction between the road sections and secondary task difficulties. The three-way interaction of the three independent variables, however, was a little larger (*M* = -339.36, *SD* = 337.96, 95% CI [-1019.80, 326.02]). It can be seen that provided that the HUD was the target display and an difficult secondary tasks was executed on it while driving on a straight road section, this led to a slight decrease in the estimated MGD.

Average Gaze Duration. Table 7 shows the results of the LME model for the average gaze duration (AGD) as dependent variable. The intercept was the same as in the model discussed above (*M* = 722.11, *SD* = 112.70, 95% CI [503.86, 945.55]). There was a considerable effect of the display position (*M* = 521.75, *SD* = 117.18, 95% CI [293.75, 759.65]). On the condition that an easy secondary task was executed during curved road sections, the estimated mean of the AGD for the HUD as target display (M_{HUD}= 1243.86) was approximately half a second higher than the estimated mean for the IC as target display (M_{IC} = 722.11). In relation to the increase of half a second, the variation due to individual differences of approximately one third of a second is quite considerable (SD_{RE} = 308.20). The effects of the road sections and the secondary task difficulty were quite small (Table 7). On condition that the IC was the target display, the estimated mean of the average gaze duration increased slightly during straight road sections ($M_{IC\_Straights}$ = 855.47) as compared to curved road sections (M_{IC_Curves} = 722.11) and during execution of difficult ($M_{IC\_Difficult}$ = 861.03) as compared to easy secondary tasks (M_{IC_Easy}= 722.11). The interaction between the display position and the secondary task difficulty (Figure 8) and between the display position

Table 7

Results of the LME Model with the dependent variable Average Gaze Duration (in ms)

	Fixed Effects				Random Effects
			Credibility Interval (95%)		
	M	*SD*	*Lower Bound*	*Upper Bound*	*SD*
Intercept [IC/ Easy Secondary Task/ Curved Road Section]	722.11	112.70	503.86	945.55	401.76
Display Position	521.75	117.18	293.75	759.65	308.20
Road Section	133.36	101.93	-66.53	332.43	95.06
Secondary Task Difficulty	138.92	106.94	-68.41	350.37	167.65
Display Position x Road Section	135.64	160.79	-183.48	445.69	292.11
Display Position x Secondary Task Difficulty	140.96	154.75	-156.18	438.00	228.24
Road Section x Secondary Task Difficulty	-13.36	142.29	-291.36	266.85	73.40
Display Position x Road Section x Secondary Task Difficulty	-190.49	203.38	-580.56	207.78	122.10
Residual					762.72

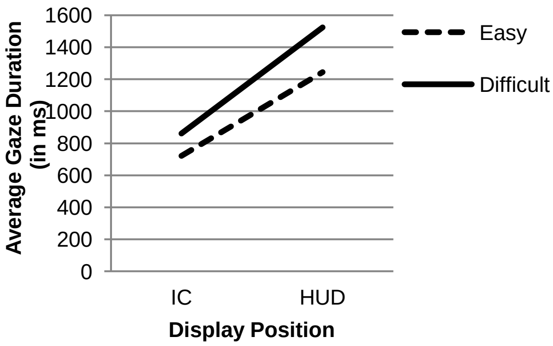

Figure 8. Interaction between the Display Position and the Secondary Task Difficulty.

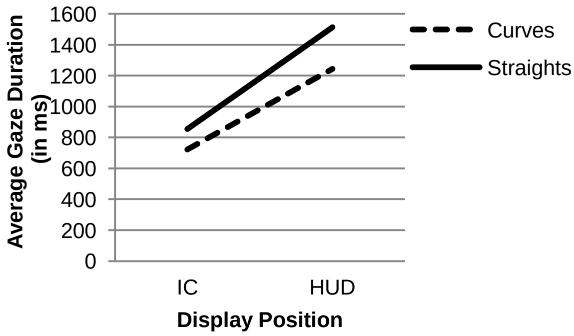

Figure 9. Interaction between the Display Position and the Road Section.

and the road sections was only small as well (Figure 9). On condition that the HUD was the target display, the estimated mean of the average gaze duration increased also only slightly during straight road sections ($M_{HUD\_Straights}$ = 1512.86) as compared to curved road sections (M_{HUD_Curves} = 1243.86) and during execution of difficult ($M_{HUD\_Difficult}$ = 1523.74) as compared to easy secondary tasks (M_{HUD_Easy}= 1243.86). Figure 8 and 9 both show the discussed effect of the display position under the different secondary task difficulties and road sections. There was only a neglectible effect of the interaction between the road sections and secondary task difficulty. However, the effect size of the three-way interaction between the display position, the secondary task difficulty and the road sections was slightly more considerable (Table 7). Provided that the HUD was the target display and the participants drove on straight sections while executing difficult secondary tasks on the HUD, there was a slight decrease in the mean of the AGD of almost 200ms.

Gaze Percentage. Table 8 presents the results for the dependent variable gaze percentage (GP). As in the other models, the intercept represented the IC as target display during easy secondary task execution and driving through curved road sections. A great effect of the display position was found (*M* =17.39, *SD* = 3.00, 95% CI [11.38, 23.39]). On the same conditions, the estimated mean GP for the HUD as target display (M_{HUD} = 59.01) increased by a little over 17 % compared to the IC as target display (M_{IC} = 41.62). However, the variation due to individual differences was very high for both intercept (SD_{RE} **=** 15.67**)** and the display position (SD_{RE} **=** 10.39). In addition, there was a considerable effect of the road section (Table 8). On condition of the IC being the target display and the execution of an easy secondary task, the estimated mean of the GP increased by a little over 8% during straight sections ($M_{IC\_Straights}$ = 49.85) compared to the curved sections (M_{IC_Curves} = 41.62). However, the variation due to individual differences of approximately 4% (Table 8) was quite high considering the described increase of 8%. Moreover, there was quite a sizeable effect of the interaction between the display position and the road section (*M* = 11.67, *SD* = 3.34, 95% CI [5.11, 18.12]). As can be seen in Figure 10, on the condition of the HUD being the target display, the increase of the estimated mean of the GP from curved (M_{HUD_Curves} = 59.01) to straight road sections ($M_{HUD\_Straights}$ = 78.914) was approximately twice as high as the increase from curved (M_{IC_Curves} = 41.62) to straight road sections ($M_{IC\_Straights}$ = 49.85) when the IC was the target display. Moreover, there was a noticeable effect of the secondary task difficulty (*M* = 6.10, *SD* = 2.11, 95% CI [1.90, 10.10]). Upon condition of the IC as target display and driving through curved road sections, the estimated mean GP during the execution of a difficult secondary task ($M_{IC\_Difficult}$ = 47.72) was almost 6% higher than during

Table 8

Results of the LME Model with the dependent variable Gaze Percentage (in %)

	Fixed Effects				Random Effects
			Credibility Interval (95%)		
	M	*SD*	*Lower Bound*	*Upper Bound*	*SD*
Intercept [IC/ Easy Secondary Task/ Curved Road Section]	41.62	3.46	34.77	48.23	15.67
Display Position	17.39	3.00	11.38	23.39	10.39
Road Section	8.23	2.15	4.00	12.47	3.92
Secondary Task Difficulty	6.10	2.11	1.90	10.10	3.44
Display Position x Road Section	11.67	3.34	5.11	18.12	8.09
Display Position x Secondary Task Difficulty	.18	3.02	-5.73	6.11	4.73
Road Section x Secondary Task Difficulty	-.10	2.83	-5.59	5.50	2.15
Display Position x Road Section x Secondary Task Difficulty	-2.37	3.93	-10.23	5.25	1.87
Residual					15.25

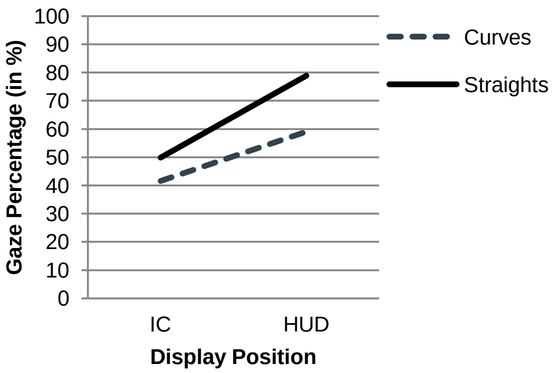

Figure 10. Interaction of the Display Position and the Road Section.

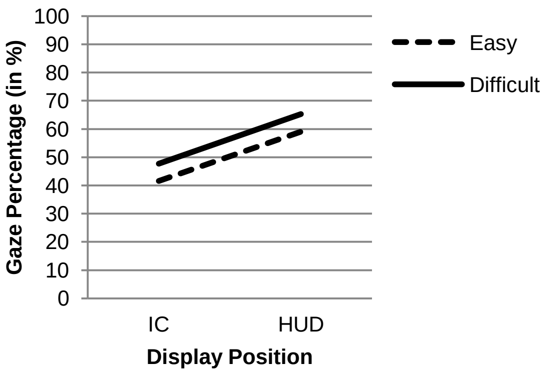

Figure 11. Interaction of the Display Position and the Secondary Task Difficulty.

an easy task (M_{IC_Easy} = 41.62). The effects of the interaction between the display location and the secondary task difficulty and between the secondary task difficulty and the road sections were only very small. The effect of the three-way interaction between the three factors was also quite small compared to the other effects. However, a slight tendency was observed that the GP decreased on condition that the HUD was the target display during difficult secondary task execution and while driving on straight road sections.

Gazes Switches. Table 9 presents the results of the LME model for the number of gaze switches. The results are on a logarithmic scale. The intercept was the same as in the other models. On condition of the IC being the target display, driving through curved road sections and executing easy secondary tasks, the participants executed exp(1.95) = 7.03 gaze switches. As can be seen in Table 9 most of the effects were quite small, which means that the changes in the number of gaze switches were very small, too. For instance, there was only a very small effect of the secondary task difficulty. Difficult tasks had an exp (.02) = 1.02 higher rate of gaze switches than easy tasks, which translated into approximately 7.2 gaze switches. The same was the case for the interaction between the display position and the road sections, the interaction of road sections and secondary task difficulty and the interaction between the display position, the secondary task difficulty and the road sections.

Nevertheless, three effects were found that were of more noticeable size. There was an effect of the display position. The HUD had an exp (-.17) = .84 lower rate of gaze switches than the IC. This translated into 5.93, approximately six, gaze switches executed when the HUD was the target display as compared to the approximately seven gaze switches of the IC. Thus, on condition that an easy task was executed while driving on curved road sections, the IC elicited one gaze switch more than the HUD. In addition, there was an effect of the interaction between the display position and the secondary task difficulty (M = -.20, SD = .08, 95% CI [-.36, -.04]). Thus, on condition of the HUD being the target display, there was an exp(-.20) = .82 lower rate of gaze switches for difficult secondary tasks as compared to easy secondary tasks. As can be seen in Figure 12, this translated into approximately one gaze switch less during difficult tasks compared to easy tasks when the HUD was the target display. Figure 13 also shows the display position effect that was described earlier.

Furthermore, there was an effect of the road section, which was of considerable size (M = -.22, SD = .06, 95% CI [-.33, -.11]). Provided that the IC was the target display, the rate of gazes switches during curved road sections was exp (-.22) = .80 lower than the rate of gaze switches during straight road sections. Thus, during curved road sections approximately one

Table 9.

Results of the LME Model with the dependent variable Number of Gaze Switches on a logarithmic scale.

	Fixed Effects				Random Effects
			Credibility Interval (95%)		
	M	*SD*	*Lower Bound*	*Upper Bound*	*SD*
Intercept [IC/ Easy Secondary Task/ Curved Road Section]	1.95	.08	1.79	2.11	.37
Display Position	-.17	.08	-.33	-.00*	.33
Road Section	-.22	.06	-.33	-.11	.11
Secondary Task Difficulty	.02	.05	-.09	.12	.09
Display Position x Road Section	-.09	.1	-.29	.10	.26
Display Position x Secondary Task Difficulty	-.20	.08	-.36	-.04	.12
Road Section x Secondary Task Difficulty	-.01	.07	-.15	.14	.05
Display Position x Road Section x Secondary Task Difficulty	-.01	.12	-.25	.21	.06

Note. *Through rounding up to two decimal places, the value became .00, however originally it is -.0006.

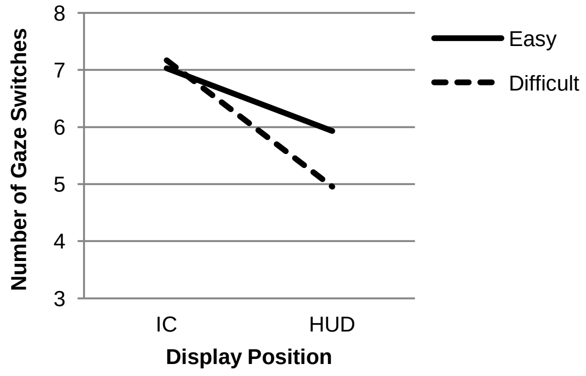

Figure 12. Interaction between the Display Position and the Road Section.

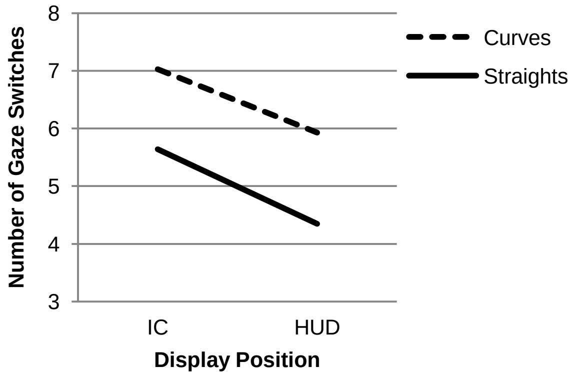

Figure 13. Interaction between the Display Position and the Secondary Task Difficulty.

and a half gaze switches were executed more between the IC and other targets than during straight road sections.

Table 9 also shows the variation due to individual differences. For the mentioned effects that were of more considerable size, the variation due to individual differences was quite high considering the relatively small changes in the number of gaze switches.

Discussion

The aim of this study was to reexamine the effects of the visual secondary task difficulty and the driving task difficulty on the drivers' visual behavior regarding different displays by means of a field study. For that purpose, the following main research question was formulated '*How do the visual secondary task difficulty and the driving task difficulty influence the drivers' visual behavior with regard to different display positions in the vehicle?',* which was divided into two sub-questions. In the next sections, the results regarding the two sub-questions and the corresponding hypotheses will be discussed. Subsequently, the limitations of the executed study as well as possible future research will be discussed, followed by a summarizing conclusion.

Discussion of the results regarding the first sub-question

The first sub-question was focused on the effects of the secondary task difficulty and reads as follows "*How does the visual secondary task difficulty influence the drivers' visual behavior with regard to different display positions in the vehicle?*". Four hypotheses were formulated and in the next paragraphs, it will be discussed whether the results of this study confirmed the hypotheses and whether they were in line with the earlier discussed literature. Afterwards, the results regarding the four gaze measures will be discussed in conjunction with each other, in order to reflect on the drivers' gaze strategies and to discuss possible underlying mechanisms.

With respect to the first hypothesis 1.1, "*The gaze percentage, the average gaze duration and the number of gaze switches are higher for a difficult secondary task than for an easy secondary task.*" the results were confirmative regarding the gaze percentage and the average gaze duration. For the gaze percentage, the findings showed that more difficult tasks that presented the drivers with more information, led to higher gaze percentages than easier tasks that presented the drivers with less information. This result was found for both displays. Even though the gaze percentage is a slightly different measure than the total gaze duration, these results seemed to be in line with the results of Ecker (2013), who found higher gaze durations during more difficult tasks.

Regarding the average gaze duration, the results showed a slight increase for difficult secondary tasks of approximately 140ms, when presented on the IC, and a slightly larger increase of approximately 280ms, when the tasks were presented on the HUD. These results are in line with the results of Victor et al. (2005). However, in their studies the increase was a little more pronounced and ranged from 300 to 400ms. This difference could be due to differences between the methods used in the two studies, such as the display position on which the tasks were presented. It is also possible that the differences are due to diverging definitions of a gaze. In the study of Victor et al. (2005), a gaze was described as "the transition to a given area, such as a display, and one or more consecutive fixations on the display until the eyes are moved to a new location" (p.169). Yet, in the current study the transition to and away from a display was not included due to limitations of the eye tracking system. This could have led to shorter average gaze durations than those found by Victor et al. (2005).

With regard to the number of gaze switches the hypothesis could not be confirmed. There was practically no difference in the number of gaze switches between the two difficulty levels, when the tasks were presented on the IC. For both difficulty levels, the drivers executed approximately seven gaze switches. Only when the tasks were presented on the HUD, there was a noticeable difference. However, this difference was contrary to the expectations due to the fact that drivers performed one gaze switch less during difficult secondary tasks compared to easy secondary tasks. In general, these results were not in line with the findings of the reviewed studies. The studies all reported higher numbers of gazes to the target displays when more difficult tasks were executed (e.g., Victor et al., 2005). A reason for the diverging results of this study could be that there is a difference between the number of gaze switches used in the current study and the number of gazes, as used in other studies. Furthermore, differences in the tasks that the drivers were asked to execute in terms of whether or not these tasks were related to the driving task and in terms of the time needed to execute them could also have led to the diverging results.

Furthermore, hypothesis 1.2, "*The maximum gaze duration is not higher for a difficult secondary task than for an easy secondary task*." could not be confirmed. With respect to the IC, the maximum gaze duration increased by approximately 360ms when executing difficult secondary tasks. Even though the maximum gaze duration was not discussed in the literature, this relatively small increase seemed to be in line with the small changes found regarding the individual gaze durations (e.g. Dingus et al., 1989). In contrast, when executing the tasks on the HUD, the maximum gaze duration was on average approximately 1450ms higher during the execution of difficult secondary tasks. Hence, for both displays there was an unexpected increase in the maximum gaze duration when executing more difficult secondary tasks. Interestingly, the increase of the gaze duration from easy to difficult tasks for the HUD was almost four times higher than the increase for the IC.

Moreover, hypothesis 1.3, *“For an easy secondary task, the number of gaze switches, the gaze percentage and the maximum and average duration of gazes focused on the HUD are higher than for the IC.”* and hypothesis 1.4, “*For a difficult task, the number of gaze switches, the gaze percentage and the maximum and average duration of gazes focused on the HUD are higher than for the IC.”* could both be confirmed with respect to the gaze percentage, the maximum and the average gaze duration. All measures yielded considerably higher values for the HUD than for the IC for both difficulty levels. These findings are in line with the results of the simulator study of Ecker (2013). However, they are not in line with, for example, the field study of Ablaßmeier et al. (2005), who found lower gaze durations for the HUD than for the IC. Again, the missing compliance with the results of the latter could be due to differences regarding the tasks that had to be executed. Ablaßmeier et al. (2005) asked their participants “(…) to read out the road signs and control the speed limits on the display” (p.2251). Both tasks seemed less time consuming than the tasks executed in the current study. In addition, in the study of Ablaßmeier et al. the tasks and their contents were driving related, whereas the tasks in the current study were not. In contrast, the tasks used in the study of Ecker (2013) were unrelated to the driving task. They entailed the search for a certain song title in a list of several titles and scrolling through that list. These tasks seemed more comparable to the tasks of the current study. Notwithstanding the above, the findings of the current study clearly emphasized that the gaze duration in terms of the three measures differed depending on the targeted display. However, there was also considerable variation found due to individual differences. Even though clear tendencies could be identified when focusing on the whole group, individual drivers differed considerably regarding the precise duration of their gazes to the displays.

With regard to the number of gaze switches, the hypotheses could not be confirmed due to the fact that fewer gaze switches were found for the HUD than the IC. Whereas the results of this study were not in line with the results of Ecker (2013), which formed the basis of the discussed hypothesis, they were in line with the results of Hada (1994). The differences to the study of Ecker could be due to differences between the used gaze measures, between the executed tasks and between a simulator and a field study. Another explanation for the diverging results could be that the average number of gaze switches for the HUD could have been reduced due to drivers who did not look away from the HUD at all during a road section. However, this only happened in approximately 5% of the cases, so the influence of these cases was probably quite small. Interestingly, these continuous gazes were not observed for the IC. In the next paragraphs further possible explanations for these results will be discussed.

Even though some of the findings were not as expected, the findings of all four gaze measures together seemed to be in line with each other and depicted a coherent picture of the drivers' gaze strategies. The drivers employed longer gazes during more difficult secondary tasks and shorter ones during easier tasks, as was found for both displays. This is highly plausible considering the fact that more difficult tasks included more information that would require more time to access it. In conjunction with this, the findings regarding the reduced number of gaze switches during difficult task execution on the HUD seem more understandable. In the same period of time, fewer but longer gazes logically lead to fewer gaze switches, whereas more and shorter gazes lead to more gaze switches. In correspondence with the high gaze durations found for the HUD, this could also explain why the number of gaze switches found for the HUD was lower than that found for the IC for both difficulty levels. Interestingly, when the IC was the target display the number of gaze switches did not change noticeably when the secondary task difficulty changed. A possible explanation for this finding could be the fact that the gaze durations for the IC only changed slightly when the secondary task difficulty changed. It seems likely that these slight changes did not lead to noticeable changes in the number of gaze switches. In contrast, during the execution of difficult tasks on the HUD the increase in the maximum gaze duration, for example, was around 1450ms and therefore approximately four times higher than the increases found for the IC. These high increases seem more likely to lead to changes in the number of gaze switches than the relatively small increases found for the IC.

In general, the findings of the four gaze measures together clearly showed that the drivers' gaze strategies changed depending on the display they were targeting. A highly plausible explanation for the different strategies could be the distance of the two displays to the driving situation. As described by Ecker (2013), the special location of the HUD allows the drivers to perceive the driving situation peripherally. In terms of the model of Wierwille, it seemed likely that this ability reduced the drivers' need to look back to the driving situation more regularly and led to fewer gaze switches and longer gazes to the HUD. In contrast, the position of the IC restricts the ability of peripherally perceiving the driving situation due to its greater distance to the driving situation. This in turn probably increased the need to look back more often and after shorter gazes, even when a task was not yet completed.

It seems highly likely that the assumed changes in the need to look back to the driving situation in correspondence with the display position and the drivers' gaze strategies in general were influenced by the mechanisms described in the risk homeostasis theory. According to Wilde (1998), the risk homeostasis theory entails that people, such as drivers, continuously compare two levels of risks, which are the target level of risk and the perceived level of risk. The target level of risk is based on a costs and benefits analysis of an action and its alternatives. The perceived level of risk is based on the subjective perception of the actual risk that a driver is exposed to. If these two levels of risks are not in line with each other, people "(…) will adjust their behavior in an attempt to eliminate any discrepancies between the two" (Wilde, 1998, p.90). Based on the discussed findings in which the HUD yielded considerably higher gaze durations and fewer gaze switches than the IC, it seems that the levels of perceived risk regarding the two displays differed considerably. It is assumed that the level of perceived risk for the HUD is considerably lower than the one for the IC, which is likely due to the HUD's proximity to the driving situation. In order to compensate for the high discrepancy between the two levels of risk, the drivers likely employed longer enduring gazes to the HUD and fewer gaze switches. In contrast, the IC seemed to induce a higher perceived level of risk. Therefore the discrepancy was smaller, leading the drivers to look at the IC for shorter durations and to look back to the driving situation more often. This assumption is also supported by the finding that even the execution of difficult secondary tasks on the HUD, which is assumed to result in a higher perceived level of risk because more information is presented, yielded longer gaze durations and fewer gazes switches than the execution of easy secondary tasks on the IC, which is assumed to result in a lower perceived level of risk.

Moreover, the findings showed that the drivers' gaze strategies also changed depending on the secondary tasks difficulty. For both displays it was found that more difficult secondary tasks led to increases in the gaze duration and to the same or fewer numbers of gaze switches. However, as described it would be assumed that more difficult secondary tasks would increase the drivers perceived level of risk, because they need to access more information, which requires them to look away from the road longer and increases their risk of an accident. This should have led to a reduced discrepancy between the two levels of risk, leading to a reduced tendency to compensate for it. This in turn was assumed to entail shorter gaze durations and more gaze switches. However, the opposite was the case in this study. A possible explanation for these findings is that the target level of risk changed, whereas the perceived level of risk stayed approximately the same. The drivers probably assessed the benefits of looking longer at more difficult tasks higher than the costs. A benefit of looking longer could have been that they would be able to finish a task within one gaze. Therefore, reducing the risk of having to start over because they forget where they were and, thus, being able to focus their attention on the driving task again faster. The increased target level of risk in turn would have led to an increase of the discrepancy between the two levels of risk. Therefore, in order to compensate the drivers employed longer gazes to both displays and fewer gaze switches in the case of the HUD. For the IC, it is possible that the changes in the target level of risk were relatively small in comparison to the HUD, resulting in only small increases in the gaze durations, which in turn are probably the reason for the unnoticeable changes in the number of gaze switches.

Moreover, the risk homeostasis theory could also explain the great individual differences that were often observed. Individuals likely perceive the level of risk differently and judge the benefits and costs of a certain action differently, too. This in turn results in diverging amounts of discrepancy between the two levels of risk and therefore leads to differences in the compensatory behavior of the drivers. The clear tendencies found on the group level seem to suggest that drivers on average seem to have comparable perceived or target levels of risk. However, looking at the individual drivers it becomes clear that many of them deviate from this average, which likely resulted in the high variations found.

Furthermore, another factor influencing the drivers' gaze behavior could have been the employed strategies to complete a certain task. This strategy might have been to access all the presented information at once or differently put completing a task within one gaze. This seems to be in line with Wierwille (1993), who argued that drivers try to sample all the information within one gaze that should, if possible, not take longer than one second. Yet, if not all information can be sampled in one second, drivers increase the gaze duration. If the 1.6 seconds limit is reached, drivers look back to the driving situation even when the task is not yet finished (Wierwille, 1993). It is possible that drivers could have completed an easy task presented on the IC in one gaze. However, regarding the difficult tasks it is possible that they had to employ multiple gazes to complete one task because they were not able to finish the task within the 1.6 seconds limit. Furthermore, the perceived level of risk during difficult tasks is probably too high or the increase in the target level of risk was not high enough to allow the drivers to look longer at the task. Thus, the same number of gaze switches could reflect different numbers of executed tasks. This could explain, too, why no considerable changes in the number of gaze switches for the IC was found between the two task difficulty levels. The relatively small increases in the gaze durations during the execution of the difficult tasks on the IC seem to support this strategy, too. However, the increases in the gaze durations for the HUD were considerably higher than those for the IC. Here, it seems more likely that drivers executed multiple tasks within one gaze. However, due to the fact that the number of completed tasks was not included in the analysis this cannot be concluded with certainty. Moreover, today's eye tracking systems, such as the one used in this study, are not yet able to clearly show whether drivers are looking at the information presented on the HUD or whether they are looking through the HUD. Further complicating the interpretation of the eye gaze behavior is the problem that the fixation of an object, such as the HUD, does not always mean that the drivers' attention is also focused on that object (Gish & Staplin, 1995). These limitations need to be considered when drawing conclusions about the drivers' gaze behavior.

Based on the results, the answer regarding the first sub-question is that the extent of the secondary task difficulty's effect on the visual behavior differed considerably depending on the display position. With regard to the IC, the effect was relatively small in terms of only slight changes in the gaze behavior. However, regarding the HUD, the secondary task difficulty evoked considerable changes in the gaze behavior, resulting in higher maximum and average gaze durations, higher gaze percentages and lower numbers of gaze switches during difficult tasks. These differences between the displays are likely due to the variations in the distance between them and the driving situation and due to the differences in the perceived level of risk of the drivers. In order to protect the primary driving task when executing the tasks on the IC, the participants had to look back to the driving task more often and after shorter gazes. However, when the HUD was the target display the drivers could perceive the driving situation peripherally, reducing their perceived level of risk and enabling them to look away longer, while still ensuring their driving safety. Moreover, it seemed that the model of Wierwille (1993) was only able to describe the gaze behavior regarding the more conventional IC. The suitability of the model regarding the HUD is questionable, because only the average gaze duration was in line with the 1.6 seconds limits. However, only complete gazes were used to compute the average gaze duration. Hence, the very long gazes that started before a road section and ended after it were excluded. Yet these gazes likely resulted in the high maximum gaze durations. Therefore, it is possible that the average gaze duration would be higher, if longer road sections would be chosen that include these long gazes. Hence, the conclusion regarding the model of Wierwille in correspondence with the HUD should be drawn with caution. In addition, the individual differences that were found need to be considered, too. For both displays, these differences suggest that some of the drivers are likely to follow the model to a higher extend than others. This emphasizes even more that conclusions regarding the model should be made with caution.

Discussion of the results regarding the second sub-question

The second sub-question was focused on the effects of the driving task difficulty on the drivers' visual behavior and reads as follows "*How does the driving task difficulty influence the drivers' visual behavior with regard to different display positions in the vehicle?*". The results regarding the formulated hypotheses were mostly confirmative as will be discussed in the next paragraph, followed by a discussion of the four gaze measures in conjunction with each other.

Hypothesis 2.1, "*The average and maximum gaze durations and the gaze percentage are lower during a difficult driving task than during an easy driving task."* was mostly confirmed. Confirmative results were found regarding the average gaze duration. During difficult driving tasks, as represented by curved road sections, the average gaze duration was decreased by approximately 130ms for the IC and by approximately 270ms for the HUD. Even though these changes were quite small, they were in line with the results found by Victor et al. (2005), who found decreases of approximately 150 to a little more than 200ms. Moreover, in the current study quite large variations due to individual differences were found. On the individual level the magnitude of the found changes in the gaze behavior seemed to be quite different compared to the group level. On the group level the findings showed that the drivers' gazes to the target displays were shorter during a difficult driving task compared to an easy driving task. However, the precise duration of these gazes seemed to vary considerably across individual drivers, with some drivers employing shorter gazes and others employing longer ones.

With respect to the maximum gaze duration only the results regarding the HUD confirmed the hypothesis. The maximum duration of the gazes focusing on the HUD was approximately 940ms higher during easier driving tasks than during difficult driving tasks. In contrast, no considerable differences were found for the IC. Moreover, considerable variations due to individual differences were observed, too. A high variation of approximately half a second was found, when the HUD was the target display. Regarding the IC, variations of around 170ms were found, which were quite high considering the negligible changes in the maximum gaze duration of only 40ms. Hence, individuals differed quite considerably with regard to the maximum time they would look at the target displays due to changing driving task difficulty.

Regarding the gaze percentage, the hypothesis was confirmed. For the IC the gaze percentage increased by more than 6% and for the HUD by even more than 17%. Hence, the drivers were spending higher percentages of time looking at the displays presenting the tasks, when the driving task was easier. This was also in line with the findings of Victor et al. (2005), who found higher total gaze durations during easier driving tasks.

Moreover, hypothesis 2.2 "*The number of gaze switches is higher during a difficult driving task than during an easy driving task.*" was confirmed. It was found that for both displays, the number of gaze switches decreased by a little more than one gaze switch during straight road sections compared to curved road sections. This was in line with the results of Tsimhoni and Green (2001).

Hypothesis 2.3, "*For an easy driving task, the number of gaze switches, the gaze percentage and the maximum and average duration of gazes focused on the HUD are higher than for the IC.*" and hypothesis 2.4, "*For a difficult driving task, the number of gaze switches, the gaze percentage and the maximum and average duration of gazes focused on the HUD are higher than for the IC.*" were both confirmed regarding the maximum and average gaze duration and the gaze percentage. For both easy and difficult driving tasks, the HUD yielded higher average and maximum gaze durations and higher gaze percentages than the IC. Regarding the number of gaze switches, the results were not confirmative. It was found that the HUD yielded less gaze switches for both driving task difficulties.

With regard to the influences of the driving task difficulty, the four gaze measures examined in conjunction with each other also depicted a clear picture about the drivers' gaze strategies. During straight road sections, hence during an easier driving task, the drivers employed longer gazes to the target displays and performed fewer gaze switches than during curved road sections. This was found for both displays regarding all gaze measures with exception of the maximum gaze duration. No considerable changes in the maximum gaze duration were found when the IC was the target display. Nevertheless, these findings show clear differences in the drivers' gaze strategies in correspondence with the driving task difficulty. Again it is likely that the processes of the risk homeostasis theory of Wilde discussed earlier could explain the drivers' behavior. It seems likely that the perceived level of risk for straight road sections was lower than for curved road sections, whereas the target level of risk stayed approximately the same. The lower perceived level of risk probably increased the discrepancy between the two levels of risk, which in turn increased the drivers' need to compensate the discrepancy. It is assumed that the compensative behavior included the higher gaze durations to the target displays and fewer gaze switches during easier driving tasks.

Furthermore, the gaze durations to the HUD were again considerably higher than for the IC and fewer gaze switches were executed, too. This seems to support the earlier assumption that the perceived level of risk is lower for the HUD than for the IC. Further support comes from the finding that for all three gaze duration measures the HUD yielded higher values during curved road sections than the IC during straight road sections. Hence, even during a more difficult driving task, which was assumed to increase the drivers' perceived level of risk, higher gaze durations were found for the HUD than the IC during an easy driving task, which was assumed to result in a lower perceived level of risk.

The question still remains why there were no noticeable changes in the maximum gaze duration between easy and difficult driving tasks when the IC was the target display. For the IC the changes in the driving task difficulty did not seem to change the drivers' gaze strategies at least regarding the maximum gaze duration. It seemed that the drivers followed the model of Wierwille (1993), as shown by the adherence to the 1.6 seconds limit for both driving task difficulties. However, this is based on the findings on the group level. As discussed, there were quite considerable individual differences found. Individual drivers differed in the maximum duration of gazes to the IC. Hence, it is highly likely that the adherence to the 1.6 seconds limit of Wierwille on the individual level is not always given. Nevertheless, the highly similar maximum gaze durations for both driving task difficulties could mean that the need to look back at the road did not considerably change when the driving task difficulty changed. It seemed that even during a less demanding driving task, the drivers still felt the need to regularly check the driving situation. Therefore, the argumentation of Wierwille (1993) that the need to look back can be found across different circumstances seemed to be true for the IC. Again, a highly plausible reason is the location of the IC that restricts the peripheral perception of the driving situation.

Another related explanation could be given by the risk homeostasis theory. It is possible that the drivers' perceived level of risk for the IC during difficult and easy driving tasks did not change as much as was assumed for the HUD, for example. Through the similarity of the perceived level of risk for the two driving task difficulties, the discrepancy between the levels was also similar and did not lead to considerable changes in the drivers' behavior. Hence, the expected increase in the maximum gaze duration during easier driving tasks was not observed. This assumption would also be in line with the relatively small increases in the average gaze duration and the gaze percentage found for the IC. Furthermore, Horrey, Alexander and Wickens (2003) argued that the costs of accessing information from the IC are higher due to the increased distance to the driving situation.

Hence when accessing information on the IC, the drivers' eyes have to travel to the display, which also counts as time looking away from the road and therefore leaves less time looking at the display itself. In contrast to the IC, the HUD reduces the access costs (Horrey et al., 2003) and allows for peripheral perception. This seemed to be supported by the considerably higher maximum gaze durations found for the HUD.

When looking at the three factors, the driving task difficulty, the display position and the secondary tasks difficulty together, a small but interesting tendency was found in the fact that the three factors did not simply add up their effects. Instead, the three factors combined lead to small decreases in the maximum and average gaze duration and in the gaze percentage. These decreases were observed when difficult secondary tasks were executed on the HUD, while driving on a straight road section. No similar results were found for the IC. Thus, even though the tasks were executed on the HUD and during a lower driving task difficulty, which were both assumed to reduce the drivers' perceived level of risk and were observed to result in higher gaze durations when examined separately, the drivers' looked slightly shorter to the HUD when they had to execute difficult tasks. Earlier it was assumed that the drivers increased their target level of risk when they executed difficult secondary tasks in order to allow themselves to look longer at the displays and thus finish a task within one gaze. However, it is assumed that in this case the perceived level of risk was already quite low due to the lower driving task difficulty and due to the fact that the HUD was the target display. In this case, it seems more likely that the drivers did not increase their target level of risk, but instead lowered it because the increase of it would have resulted in even longer gazes than they already employed. These very long gazes could be potentially dangerous. However, the decrease in the target level of risk would have resulted in a reduced discrepancy that is assumed to result in shorter gaze durations. This in turn should increase the drivers' safety. It seems thus that the drivers' had a limit at which they stopped changing their perceived and target level of risk in order to ensure their safety. Drivers likely differ in where this limit would be and how they adjust their levels of risk, explaining the high variations due to individual differences that were often observed.

With regard to the second sub-question the answer is that the extent of the effects of the driving task difficulty on the drivers' visual behavior also varied depending on the display position. In correspondence with the HUD, the effects of the driving task difficulty were more pronounced for most of the measures except of the number of gaze switches. Drivers clearly changed their gaze strategies in light of changing driving task difficulty but even more so in correspondence with the display position. As with the first sub-question, it was assumed that these changes in gaze strategies are due to changes in the drivers' perceived and target level of risk. The individual differences that were observed were also assumed to be due to divergences in the precise levels of risk that drivers' perceived and targeted. Furthermore, also in light of the driving task difficulty, the model of Wierwille (1993) seemed to be less suitable to explain the drivers' gaze behavior regarding the HUD. However, this conclusion should be drawn with caution, due to the fact that considerable individual differences were found that showed that some drivers adhered more to the model than others.

Additional findings

With regard to the additional hypothesis 3.1, '*On average, the maximum and average gaze duration do not exceed the 1.6 seconds limit.*' the results were not confirmative regarding the maximum gaze duration. The maximum gaze durations found for the HUD were above the 1.6 seconds limit described by Wierwille (1993) and even above the two seconds limit of the NHTSA. This was true for all secondary task and driving task difficulties. As discussed, this is likely due to a reduction of the perceived level of risk of the drivers. This reduction was assumed to be due to special location of the HUD that likely increases the drivers' sense of safety. In contrast, when the IC was the target display the maximum gaze duration exceeded the 1.6 seconds limit only once during difficult secondary tasks and only with a little more than 100ms. With regard to the average gaze duration, the 1.6 seconds limit was on average neither exceeded for the IC nor for the HUD. It seemed that the model of Wierwille (1993) was able to predict the drivers' gaze strategies better when the IC was the target display. Here almost all results were confirmative of the model and the 1.6 seconds limit. However, considerable individual differences were found, suggesting that some drivers adhered more to the model than others. As discussed, the suitability of Wierwille's model to explain the drivers' gaze strategies regarding the HUD was questionable, at least regarding the maximum gaze durations. Only the average gaze durations for the HUD were in line with the model of Wierwille (1993). Yet as discussed earlier, the average gaze duration could have been longer when longer road sections were analyzed. Higher average gaze durations for the HUD would also be more in line with the other more increased measures. Thus, the maximum gaze duration seems to be better suitable for drawing conclusions regarding the suitability of Wierwille's model. However, quite high individual differences were found for the HUD, too. Hence, even though the gaze strategies of the drivers on the group level seemed to follow the model of Wierwille regarding the IC and partially regarding the HUD, some drivers probably followed the model more than others.

Furthermore, the analyses of the percentiles showed that only the average gaze duration for the IC was in line with the two seconds limit of the NHTSA. The HUD was above the limit for both the average and maximum gaze durations. In addition, difficult tasks and straight road sections yielded average and maximum gaze durations that were above the limit, too. Hence, special attention should be paid to these three aspects. However, all factor levels were combined in these results. Considering the results of the LME models that examined the influences of the different factors and their levels on the maximum and average gaze duration separately, the results were a little bit different. For example, the estimated mean of the average gaze duration for the HUD was below the two seconds limit of the NHTSA. The maximum gaze duration of the IC was below the limit, too. Based on these results, it could be argued that the IC seemed to yield better results regarding the gaze behavior because it complies to a higher degree with the NHTSA guidelines. However, the HUD was not mentioned in these guidelines. Hence, the high gaze durations cannot be judged in terms of the two seconds limit of the NHTSA. In addition, the HUD was described to have many advantages over the IC, such as lower costs for accessing information (Horrey & Wickens, 2002), the possibility of peripheral perception of the driving situation and better driving performance (Ecker, 2013). In light of the current trends, the question remains whether these advantages still prevail with higher amounts of information or whether other problems get more pronounced, such as cognitive capture or perceptual tunneling (e.g., Milicic, 2012). These aspects need to be considered when presenting drivers with more information on more prominent places in the drivers' visual fields.

Moreover, the comparison of the three factors with each other clearly showed that the display position had the strongest effect on the drivers' gaze behavior and their gaze strategies. The changes in the gaze behavior in terms of the gaze durations were 2 to 40 times more pronounced than the changes due to the other two factors. Only for the number of gaze switches the effect of the display position was less pronounced. In comparison to the display position, the effects of the secondary and driving task difficulty were relatively small. Mostly in interaction with the display position, hence when the HUD was the target display, the effects of these two factors became more pronounced.

Limitations

This study and the results of it were influenced by several limitations. Firstly, the participants were asked to execute the visual secondary tasks when they had capacities left. Hence, they were free regarding the decision when to execute a task and how many in a row. However, many participants completed one task item after the other, sometimes even with the motivation of completing as much as possible. Yet in a real driving situation with more traffic around the driver, the consecutive execution of different tasks seems unrealistic. First of all, it seems relatively unlikely that the drivers would be presented with so many additional tasks to execute consecutively in such short time. It seems more likely that the driving situation in an uncontrolled environment would disallow them to execute that many tasks in that manner because it would be too dangerous. Moreover, only one driving scenario was used where the participants had to follow the rabbit car at a vehicle speed up to approximately 60km/h. This was done to ensure the participants safety while they were distracted from the driving tasks. However, under other circumstances, such as on city streets or the freeway, quite different situations arise due to more traffic, pedestrians, higher speeds and more unexpected events that are likely to lead to changes in the drivers' gaze behavior. In general, it seems likely that the HUD would still lead to higher gaze durations than the IC. However, it is possible that drivers would look less often or shorter to the HUD than found in this study under other traffic circumstances. In addition, due to the limits of this thesis only the gaze behavior was analyzed. Other aspects, such as the driving performance or the number of completed task items in correspondence with the gaze behavior, were not analyzed. Therefore, the conclusions regarding the gaze strategies employed for the task completion on different displays could only be made with caution. In addition, the chosen road sections were relatively short, whereupon some gazes were removed that could have yielded slightly other results. In correspondence with the road sections, only complete gazes were used to compute the average gaze duration. As discussed, these gazes probably would have increased the average gaze duration some more. Lastly, today's available eye tracking systems are not able to differentiate between looking at the HUD or looking through it, which could have influenced the results, too.

Future research

In future research the goal should be to eliminate the discussed limitations or at least to control them as much as possible without endangering the participants. Firstly, different driving situations should be examined, with more variation in the driving task in terms of speed, changing lanes, with different amounts of traffic and with pedestrians crossing the street, etcetera. This could shed light on possible safety problems regarding relatively long gazes to the HUD, as were found in this study, and it would increase the generalizability of the results. Furthermore, the gaze behavior should be analyzed in correspondence with the driving performance. According to Ecker (2013), looking at the HUD led to better driving performance, as compared to looking at the IC. Thus, in order to be able to draw conclusions about the amount of information that can be presented on the displays without decreasing the safety, the driving performance needs to be examined, too. In addition, in order to be able to clearly examine the gaze strategies regarding the task completion, the gaze behavior should be analyzed in combination with the number of executed task items. This would further enrich the knowledge regarding the executed gaze strategies and therefore aid in deciding what amounts of information can safely be presented on different displays. Furthermore, longer road sections should be examined, too, in order to examine whether the average gaze duration change considerably and to be able to draw more certain conclusions regarding the suitability of the model of Wierwille (1993). Additionally, it would be interesting to examine whether the different types of secondary tasks have different influences on the drivers gaze behavior. This could further help with regard to the question whether it is safe to include more information or what kind of information is more visually demanding and should be reduced. Moreover, it was discussed that the NHTSA guidelines were focused on the more traditional displays and not on the HUD. Thus, future research should also look into the development of guidelines for the HUD.

Conclusion

In general the results of this study were in line with the results of previous literature to a high degree. The few differences that were found regarding the number of gaze switches or slightly less pronounced changes in the gaze behavior were attributed to differences in the studies, such as the difference regarding the relatedness of the secondary tasks to the driving task. Furthermore, the study showed that the effects of the visual secondary task difficulty and the driving task difficulty differed considerably depending on the display position. The display position seemed to have the strongest effect and led to the most considerable changes in the drivers’ gaze behavior compared to the other two factors. The effects of the other two were quite comparable to each other. In general, the drivers clearly changed their gaze behavior with regard to the two displays in dependence of the different amounts of information presented and the driving task difficulty. When the display was further away from the driving situation, as was the case for the IC, the drivers seemed to change their behavior in terms of shorter gazes to the display and more gaze switches to ensure their safety across all circumstances. It was assumed that this was due to higher perceived levels of risk. However, when the display was closer to the driving situation, the perceived level of risk seemed to be lower leading to longer gazes to the displays and fewer gaze switches. Hence, drivers seemed to work against the safety benefits of the HUD, which could be potentially dangerous when planning on presenting the drivers with different amounts of information on the HUD. However, small tendencies were observed, that showed that the drivers did not prolong their gazes to the HUD above and beyond. Instead, they seemed to recognize the fact that their gazes away from the driving situation would become too long to still be safe and tended to employ shorter gazes instead. In light of the trends that include more and more technology and information in the vehicle this last finding was a quite reassuring outcome. Nevertheless, the long gazes focusing on the HUD could be potentially dangerous. Therefore, it could be beneficial to decrease the target level of risk of the drivers' in order to ensure their safety. Furthermore, future research is necessary including, among others, the combined examination of the gaze behavior and driving performance in order to draw definite conclusions regarding potential safety issues, the safe implementation of these technologies and the desirable amounts of information presented on the displays.

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Appendix

Appendix A

Table 1

Actual, adjusted and approximated size of the three displays and the surroundings

	Actual size (in meter)	Adjusted size (+ 15%, in meter)	Approximated size (in meter)
HUD			
X			.10
Y			.08
MMI			
X	.17	.20	
Y	.10	.12	
IC			
X	.10	.12	
Y	.10	.12	
Surroundings			
X			1.40
Y			1.00

Appendix B

Questionnaire regarding the participants' personal details.

1. Fragebogen zur Person

Beginnend möchten wir Informationen zu Ihrer Person erfassen. Füllen Sie dafür bitte die folgenden Fragen aus.

Sollten Sie Rückfragen haben oder Unklarheiten entstehen, wenden Sie sich bitte an den Versuchsleiter.

A. Personenbezogene Daten

1. Welches Geschlecht haben Sie?

☐ weiblich ☐ männlich ☐ sonntiges

2. Wie alt sind Sie? ___________

3. Ist Deutch Ihre Mutterspraache?

☐ Ja ☐ Nein

4. Seit wie vielen Jahren besitzen Sie Ihren Führerschein? ___________

5. Wie viele Kilometer fahren Sie durchschnittlich im Jahr?

☐ bis 5.000 km
☐ 5.000 - 10.000 km
☐ 11.000 - 20.000 km
☐ 21.000 - 30.000 km
☐ 31.000 - 40.000 km
☐ 41.000 - 50.000 km
☐ mehr als 50.000 km

6. Mit welcher Schaltung fahren Sie in Ihrem Auto

☐ Manuelle Gangschaltung
☐ Automatikschaltung

7. Wie viel Erfahrung haben Sie mit dem Autofahren mit einem Head-Up Display?

☐ keine Erfahrung / noch nie mit gefahren
☐ wenig Erfahrung / ein paarmal mit gefahren
☐ mäßig viel Erfahrung / mehrmals mig gefahren, aber unregelmäßig
☐ viel Erfahrung / regelmaßige Nutzung
☐ sehr viel Erfahrung / Nutzung bei jeder Fahrt

Appendix C

Table 2

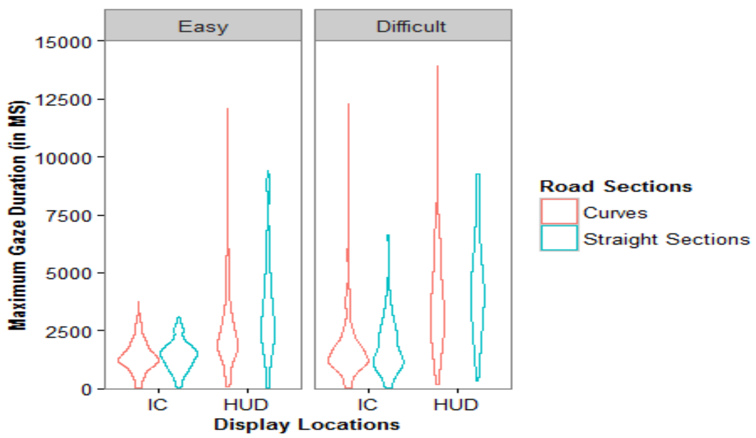
Overview of the procedure using the example of the first group

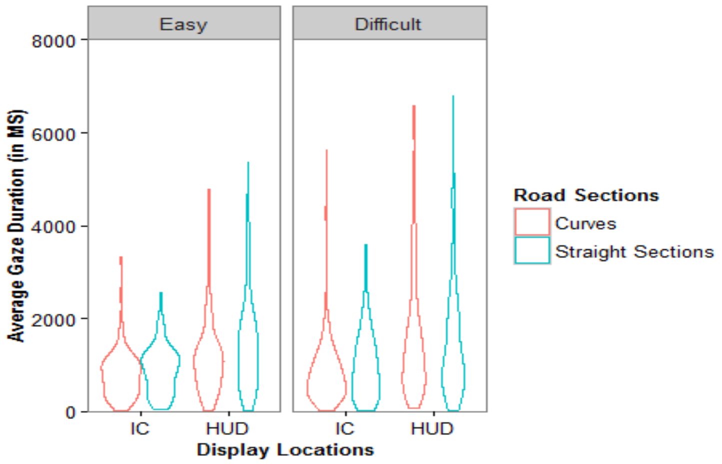
Part of the study	Procedure
First part	
	Introduction
	faceLAB™ calibration part 1 and questionnaire 1
	faceLAB™ calibration part 2
	Explanation of the three tasks (driving, visual attention and visual secondary task)
	Practice rounds
	First baseline ride
	Marking the SEA scale
Second part	
	Task execution of the HUD
	Pictures (3 Levels = 3 Rounds) – Afterwards SEA Scale
	Lists (3 Levels = 3 Rounds) – Afterwards SEA Scale
	Texts (3 Levels = 3 Rounds) – Afterwards SEA Scale
	Task execution on the IC
	Lists (3 Levels = 3 Rounds) – Afterwards SEA Scale
	Texts (3 Levels = 3 Rounds) – Afterwards SEA Scale
	Pictures (3 Levels = 3 Rounds) – Afterwards SEA Scale
	Task execution on the MMI
	Texts (3 Levels = 3 Rounds) – Afterwards SEA Scale
	Pictures (3 Levels = 3 Rounds) – Afterwards SEA Scale
	Lists (3 Levels = 3 Rounds) – Afterwards SEA Scale
	Second baseline ride
	Marking the SEA scale
Third part	
	Questionnaire 2
	Gift presentation
	End of the study

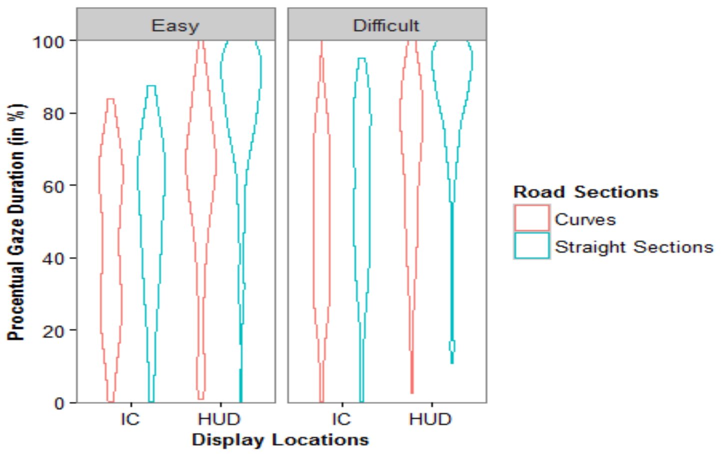
Appendix D

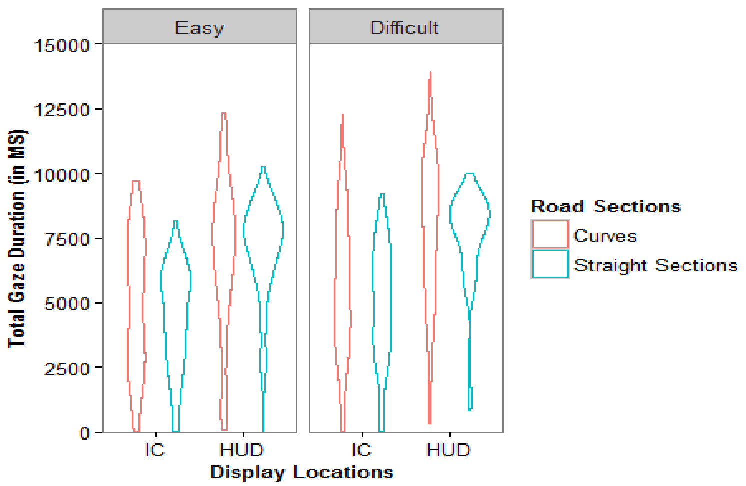
Explorative Data Analysis with exemplary R codes.

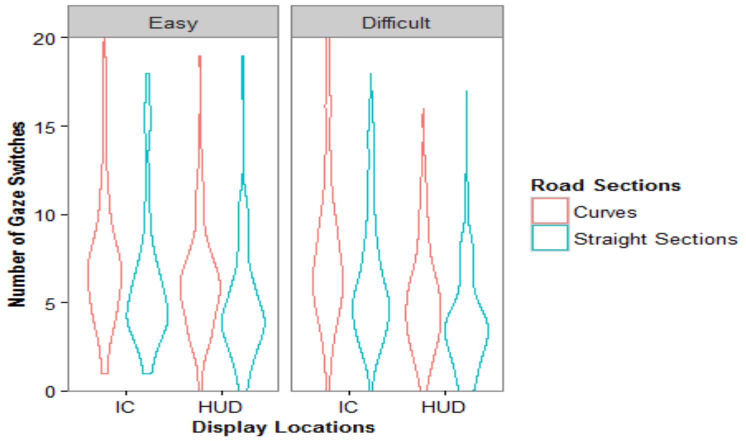
```
D <-
  read.spss("Datensatz_SchmidtMAVW_130616_v2.sav",
            to.data.frame = TRUE) %>%
  as_data_frame() %>%
  select(VP:Roadsection, Mean_MS_Target:PGD_MS_Target) %>%
  filter(!is.na(Max_MS_Target)) %>%
  mutate(Obs = row_number())

## Warning in read.spss("Datensatz_SchmidtMAVW_130616_v2.sav", to.data.frame
## = TRUE): Datensatz_SchmidtMAVW_130616_v2.sav: Unrecognized record type 7,
## subtype 18 encountered in system file

#D$RoadsectionRec <- relevel(D$RoadsectionRec, "Straight Sections")
D$Display <- relevel(D$Display, "IC" )

Drenamed<-D
Drenamed<- rename(Drenamed, Road_Sections = RoadsectionRec)
Drenamed<- rename(Drenamed, Display_Locations = Display)
Drenamed<- rename(Drenamed, Secondary_Task_Difficulty = SecTaskDif)

Drenamed %>%
  ggplot(aes(y = Max_MS_Target,
             x = Display_Locations,
             col = Road_Sections)) +
 labs (fill = "Road Sections")+
   geom_violin() +
  facet_grid(~Secondary_Task_Difficulty )+
    scale_y_continuous("Maximum Gaze Duration (in MS)", limits = c(0, 15000), breaks=seq(0,
15000, by = 2500), expand = c(0,0)) +
  scale_x_discrete("Display Locations") +
  labs(colour ='Road Sections') +
  theme_bw() +
   theme(axis.title.x = element_text(family="sans", face="bold", size=10),
      axis.title.y = element_text(family="sans", face="bold", size=10, angle=90),
      axis.text.x = element_text(family="sans",  size=10),
      axis.text.y = element_text(family="sans",  size=10),
      panel.grid.major = element_line( colour = "white"),
      panel.grid.minor = element_line( colour = "white"),
      #panel.border = element_rect(colour = "white"),
      #axis.line.x = element_line(colour= "black"),
      #axis.line.y = element_line(colour= "black"),
      legend.title =element_text(family="sans", face = "bold", size=10),
      legend.text = element_text(family="sans",  size=10),
      strip.text.x = element_text(family="sans", size=10)
  )
```




Easy
Difficult
Average Gaze Duration (in MS)
8000
6000
4000
2000
0
IC
HUD
IC
HUD
Display Locations
Road Sections
Curves
Straight Sections


Easy
Difficult
Procentual Gaze Duration (in %)
100
80
60
40
20
0
IC
HUD
IC
HUD
Display Locations
Road Sections
Curves
Straight Sections


Easy
Difficult
Total Gaze Duration (in MS)
15000
12500
10000
7500
5000
2500
0
IC
HUD
IC
HUD
Display Locations
Road Sections
Curves
Straight Sections

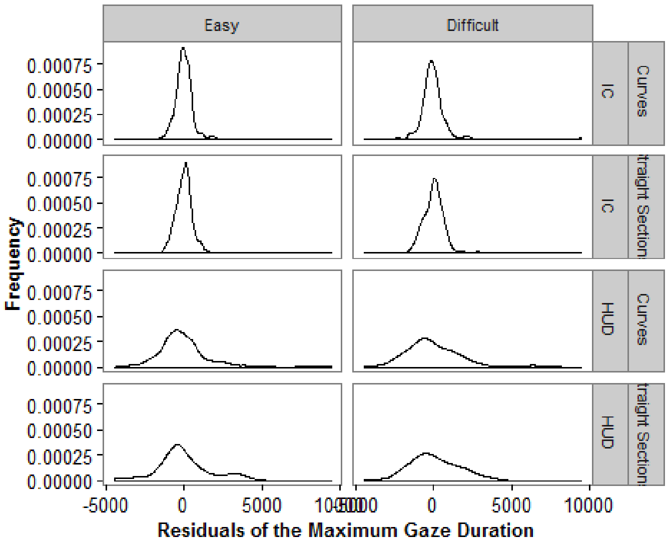


Maximum Gaze Duration

```
M1 <- lmer(Max_MS_Target ~ Display * RoadsectionRec * SecTaskDif +
             ((Display + RoadsectionRec + SecTaskDif)|VP),
           data = D)
summary(D)

##        VP          Gender      Display     SecTaskType      SecTaskDif
##  Min.   : 3.00   female:503   IC :514   Pictures:351   Easy     :514
##  1st Qu.:11.00   male  :536   HUD:525   Lists   :339   Difficult:525
##  Median :18.00                          Texts   :349
##  Mean   :18.49
##  3rd Qu.:26.00
##  Max.   :34.00
##
##       Laps                  RoadsectionRec              Roadsection
##  Min.   : 2.00   Curves            :516    Curve 1           :255
##  1st Qu.:10.00   Straight Sections:523    Curve 2           :261
##  Median :17.00                             Straight Section 1:258
##  Mean   :16.92                             Straight Section 2:265
##  3rd Qu.:24.00
##  Max.   :30.00
##
##  Mean_MS_Target   Max_MS_Target   Sum_MS_Target   GazeSwitch_Target
##  Min.   :  16.0   Min.   :   16   Min.   :   16   Min.   : 0.000
##  1st Qu.: 505.9   1st Qu.: 1234   1st Qu.: 4214   1st Qu.: 4.000
##  Median : 950.7   Median : 2012   Median : 6428   Median : 5.000
##  Mean   :1154.1   Mean   : 2620   Mean   : 6130   Mean   : 5.952
##  3rd Qu.:1434.8   3rd Qu.: 3454   3rd Qu.: 8134   3rd Qu.: 8.000
##  Max.   :6788.0   Max.   :13934   Max.   :13934   Max.   :20.000
##  NA's   :53
##  PGD_MS_Target           Obs
##  Min.   :  0.1283   Min.   :   1.0
##  1st Qu.: 42.3045   1st Qu.: 260.5
##  Median : 65.2368   Median : 520.0
##  Mean   : 60.7250   Mean   : 520.0
##  3rd Qu.: 81.6498   3rd Qu.: 779.5
##  Max.   :100.0000   Max.   :1039.0
##

summary(M1)
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## Max_MS_Target ~ Display * RoadsectionRec * SecTaskDif + ((Display +
##     RoadsectionRec + SecTaskDif) | VP)
##    Data: D
##
## REML criterion at convergence: 17912.9
##
## Scaled residuals:
```

```
##     Min      1Q  Median      3Q     Max
## -3.3342 -0.4527 -0.0631  0.3071  7.0823
##
## Random effects:
##  Groups   Name                            Variance Std.Dev. Corr
##  VP       (Intercept)                      264915   514.7
##           DisplayHUD                      1017033  1008.5   -0.25
##           RoadsectionRecStraight Sections  138926   372.7   -0.84  0.67
##           SecTaskDifDifficult              367170   605.9    0.72  0.31
##  Residual                                 1771319  1330.9
##  -0.25
##
## Number of obs: 1039, groups:  VP, 24
##
## Fixed effects:
##                                                                Estimate
## (Intercept)                                                     1355.47
## DisplayHUD                                                      1297.24
## RoadsectionRecStraight Sections                                   43.39
## SecTaskDifDifficult                                              351.65
## DisplayHUD:RoadsectionRecStraight Sections                       873.34
## DisplayHUD:SecTaskDifDifficult                                   892.06
## RoadsectionRecStraight Sections:SecTaskDifDifficult               29.22
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult  -335.47
##                                                                Std. Error
## (Intercept)                                                        160.12
## DisplayHUD                                                         268.47
## RoadsectionRecStraight Sections                                    184.37
## SecTaskDifDifficult                                                207.99
## DisplayHUD:RoadsectionRecStraight Sections                         235.30
## DisplayHUD:SecTaskDifDifficult                                     235.40
## RoadsectionRecStraight Sections:SecTaskDifDifficult                235.20
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult     330.72
##                                                                t value
## (Intercept)                                                      8.465
## DisplayHUD                                                       4.832
## RoadsectionRecStraight Sections                                  0.235
## SecTaskDifDifficult                                              1.691
## DisplayHUD:RoadsectionRecStraight Sections                       3.712
## DisplayHUD:SecTaskDifDifficult                                   3.790
## RoadsectionRecStraight Sections:SecTaskDifDifficult              0.124
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult  -1.014
##
## Correlation of Fixed Effects:
##             (Intr) DspHUD RdsRSS ScTsDD DsHUD:RRSS DHUD:ST RRSS:S
## DisplayHUD  -0.465
## RdsctnRcStS -0.722  0.508
## ScTskDfDffc -0.153  0.401  0.317
## DspHUD:RRSS  0.385 -0.444 -0.648 -0.295
## DspHUD:STDD  0.386 -0.445 -0.334 -0.571  0.507
## RdsRSS:STDD  0.386 -0.230 -0.649 -0.571  0.507      0.505
## DHUD:RRSS:S -0.274  0.317  0.461  0.406 -0.710     -0.708  -0.711
D$resid_M1 <- residuals(M1)

DrenamedM1<-D
DrenamedM1<- rename(DrenamedM1, Road_Sections = RoadsectionRec)
DrenamedM1<- rename(DrenamedM1, Display_Locations = Display)
DrenamedM1<- rename(DrenamedM1, Secondary_Task_Difficulty = SecTaskDif)

DrenamedM1 %>%
  ggplot(aes(x = resid_M1)) +
  geom_density() +
  facet_grid(Display_Locations ~ Road_Sections ~ Secondary_Task_Difficulty) +
  scale_y_continuous("Frequency") +
  scale_x_continuous("Residuals of the Maximum Gaze Duration")+
  theme_bw() +
```

```
  theme(axis.title.x = element_text(family="sans", face="bold", size=10),
     axis.title.y = element_text(family="sans", face="bold", size=10, angle=90),
     axis.text.x = element_text(family="sans",  size=10),
     axis.text.y = element_text(family="sans",  size=10),
     panel.grid.major = element_line( colour = "white"),
     panel.grid.minor = element_line( colour = "white"),
     legend.title =element_text(family="sans", face = "bold", size=10),
     legend.text = element_text(family="sans",  size=8),
     strip.text.x = element_text(family="sans", size=8),
     strip.text.y = element_text(family="sans", size=8)
 )
```

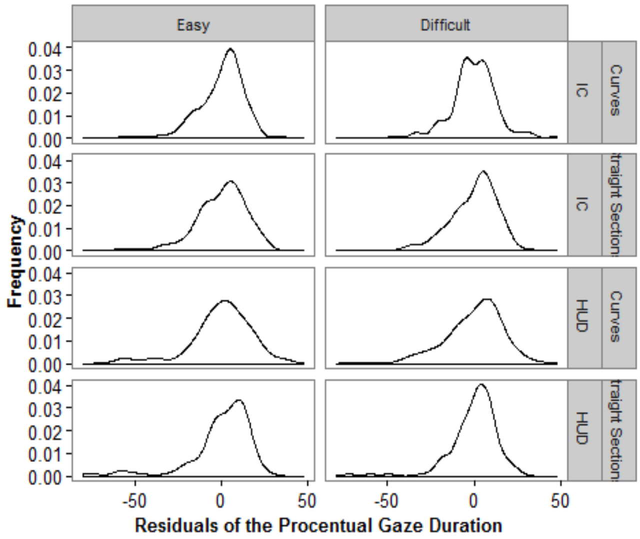


Procentual Gaze Duration

```
M3 <- lmer(PGD_MS_Target ~ Display * RoadsectionRec * SecTaskDif +
             ((Display + RoadsectionRec + SecTaskDif)|VP),
           data = D)

summary(M3)

## Linear mixed model fit by REML ['lmerMod']
## Formula:
## PGD_MS_Target ~ Display * RoadsectionRec * SecTaskDif + ((Display +
##     RoadsectionRec + SecTaskDif) | VP)
##    Data: D
##
## REML criterion at convergence: 8771.5
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -5.1033 -0.4542  0.1484  0.6039  3.0377
##
## Random effects:
##  Groups   Name                        Variance Std.Dev. Corr
##  VP       (Intercept)                 375.015  19.365
##           DisplayHUD                  163.272  12.778   -0.67
##           RoadsectionRecStraight Sections  45.776   6.766   -0.73  0.41
##           SecTaskDifDifficult           7.803   2.793    0.83 -0.70 -0.24
##  Residual                             241.901  15.553
##
## Number of obs: 1039, groups:  VP, 24
##
## Fixed effects:
##                                                                 Estimate
## (Intercept)                                                     41.18248
## DisplayHUD                                                      17.77841
```

```
## RoadsectionRecStraight Sections                                   8.42244
## SecTaskDifDifficult                                               6.00568
## DisplayHUD:RoadsectionRecStraight Sections                       11.23516
## DisplayHUD:SecTaskDifDifficult                                    0.22586
## RoadsectionRecStraight Sections:SecTaskDifDifficult              -0.03087
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult -2.15058
##                                                                 Std. Error
## (Intercept)                                                        4.20093
## DisplayHUD                                                         3.29436
## RoadsectionRecStraight Sections                                    2.40425
## SecTaskDifDifficult                                                2.03885
## DisplayHUD:RoadsectionRecStraight Sections                         2.75456
## DisplayHUD:SecTaskDifDifficult                                     2.75217
## RoadsectionRecStraight Sections:SecTaskDifDifficult                2.75027
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult    3.86759
##                                                                t value
## (Intercept)                                                      9.803
## DisplayHUD                                                       5.397
## RoadsectionRecStraight Sections                                  3.503
## SecTaskDifDifficult                                              2.946
## DisplayHUD:RoadsectionRecStraight Sections                       4.079
## DisplayHUD:SecTaskDifDifficult                                   0.082
## RoadsectionRecStraight Sections:SecTaskDifDifficult             -0.011
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult  -0.556
##
## Correlation of Fixed Effects:
##             (Intr) DspHUD RdsRSS ScTsDD DsHUD:RRSS DHUD:ST RRSS:S
## DisplayHUD  -0.641
## RdsctnRcStS -0.592  0.439
## ScTskDfDffc -0.015  0.141  0.369
## DspHUD:RRSS  0.172 -0.426 -0.581 -0.352
## DspHUD:STDD  0.173 -0.428 -0.301 -0.683  0.508
## RdsRSS:STDD  0.173 -0.219 -0.583 -0.682  0.507      0.505
## DHUD:RRSS:S -0.123  0.303  0.415  0.485 -0.710     -0.709  -0.711
```

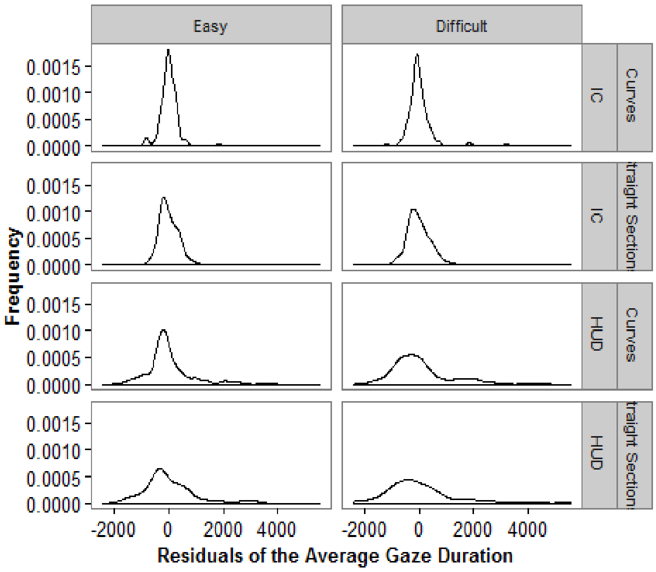
```
D$resid_M3 <- residuals(M3)

DrenamedM3<-D
DrenamedM3<- rename(DrenamedM3, Road_Sections = RoadsectionRec)
DrenamedM3<- rename(DrenamedM3, Display_Locations = Display)
DrenamedM3<- rename(DrenamedM3, Secondary_Task_Difficulty = SecTaskDif)

DrenamedM3 %>%
  ggplot(aes(x = resid_M3)) +
  geom_density() +
  facet_grid(Display_Locations ~ Road_Sections ~ Secondary_Task_Difficulty) +
  scale_y_continuous("Frequency") +
  scale_x_continuous("Residuals of the Procentual Gaze Duration")+
  theme_bw() +
   theme(axis.title.x = element_text(family="sans", face="bold", size=10),
      axis.title.y = element_text(family="sans", face="bold", size=10, angle=90),
      axis.text.x = element_text(family="sans",  size=10),
      axis.text.y = element_text(family="sans",  size=10),
      panel.grid.major = element_line( colour = "white"),
      panel.grid.minor = element_line( colour = "white"),
     # panel.border = element_rect(colour = "white"),
      #axis.line.x = element_line(colour= "black"),
      #axis.line.y = element_line(colour= "black"),
       legend.title =element_text(family="sans", face = "bold", size=10),
      legend.text = element_text(family="sans",  size=8),
      strip.text.x = element_text(family="sans", size=8),
      strip.text.y = element_text(family="sans", size=8)
  )
```



Average Gaze Duration

```
D1 <-
  D %>%
  filter(!is.na(Mean_MS_Target))

M4 <- lmer(Mean_MS_Target ~ Display * RoadsectionRec * SecTaskDif +
             ((Display + RoadsectionRec + SecTaskDif)|VP),
           data = D)

summary(M4)

## Linear mixed model fit by REML ['lmerMod']
## Formula:
## Mean_MS_Target ~ Display * RoadsectionRec * SecTaskDif + ((Display +
##     RoadsectionRec + SecTaskDif) | VP)
##    Data: D
##
## REML criterion at convergence: 15925.6
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.1416 -0.4283 -0.1166  0.3015  7.1692
##
## Random effects:
##  Groups   Name                          Variance Std.Dev. Corr
##  VP       (Intercept)                   234307   484.1
##           DisplayHUD                    205676   453.5    -0.46
##           RoadsectionRecStraight Sections  21993   148.3    -0.82  0.35
##           SecTaskDifDifficult             20756   144.1     0.78  0.18
##  Residual                               600483   774.9
##  -0.60
##
## Number of obs: 986, groups:  VP, 24
##
## Fixed effects:
##                                                              Estimate
## (Intercept)                                                    712.74
## DisplayHUD                                                     541.99
## RoadsectionRecStraight Sections                                149.09
## SecTaskDifDifficult                                            148.71
## DisplayHUD:RoadsectionRecStraight Sections                     109.15
## DisplayHUD:SecTaskDifDifficult                                 134.40
## RoadsectionRecStraight Sections:SecTaskDifDifficult            -25.63
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult -158.91
##                                                              Std. Error
```

```
## (Intercept)                                                          121.66
## DisplayHUD                                                           136.63
## RoadsectionRecStraight Sections                                      102.66
## SecTaskDifDifficult                                                  102.17
## DisplayHUD:RoadsectionRecStraight Sections                           139.64
## DisplayHUD:SecTaskDifDifficult                                       139.29
## RoadsectionRecStraight Sections:SecTaskDifDifficult                  137.59
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult       198.00
##                                                                  t value
## (Intercept)                                                        5.859
## DisplayHUD                                                         3.967
## RoadsectionRecStraight Sections                                    1.452
## SecTaskDifDifficult                                                1.456
## DisplayHUD:RoadsectionRecStraight Sections                         0.782
## DisplayHUD:SecTaskDifDifficult                                     0.965
## RoadsectionRecStraight Sections:SecTaskDifDifficult               -0.186
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult  -0.803
##
## Correlation of Fixed Effects:
##             (Intr) DspHUD RdsRSS ScTsDD DsHUD:RRSS DHUD:ST RRSS:S
## DisplayHUD  -0.557
## RdsctnRcStS -0.596  0.423
## ScTskDfDffc -0.219  0.393  0.422
## DspHUD:RRSS  0.292 -0.511 -0.671 -0.347
## DspHUD:STDD  0.295 -0.512 -0.347 -0.672  0.501
## RdsRSS:STDD  0.297 -0.263 -0.680 -0.679  0.500      0.498
## DHUD:RRSS:S -0.206  0.360  0.473  0.471 -0.702     -0.699  -0.695

D1$resid_M4 <- residuals(M4)

DrenamedM4<-D1
DrenamedM4<- rename(DrenamedM4, Road_Sections = RoadsectionRec)
DrenamedM4<- rename(DrenamedM4, Display_Locations = Display)
DrenamedM4<- rename(DrenamedM4, Secondary_Task_Difficulty = SecTaskDif)

DrenamedM4 %>%
  ggplot(aes(x = resid_M4)) +
  geom_density() +
  facet_grid(Display_Locations ~ Road_Sections ~ Secondary_Task_Difficulty) +
  scale_y_continuous("Frequency") +
  scale_x_continuous("Residuals of the Average Gaze Duration")+
  theme_bw() +
   theme(axis.title.x = element_text(family="sans", face="bold", size=10),
      axis.title.y = element_text(family="sans", face="bold", size=10, angle=90),
      axis.text.x = element_text(family="sans",  size=10),
      axis.text.y = element_text(family="sans",  size=10),
      panel.grid.major = element_line( colour = "white"),
      panel.grid.minor = element_line( colour = "white"),
      legend.title =element_text(family="sans", face = "bold", size=10),
      legend.text = element_text(family="sans",  size=8),
      strip.text.x = element_text(family="sans", size=8),
      strip.text.y = element_text(family="sans", size=8)
  )
```

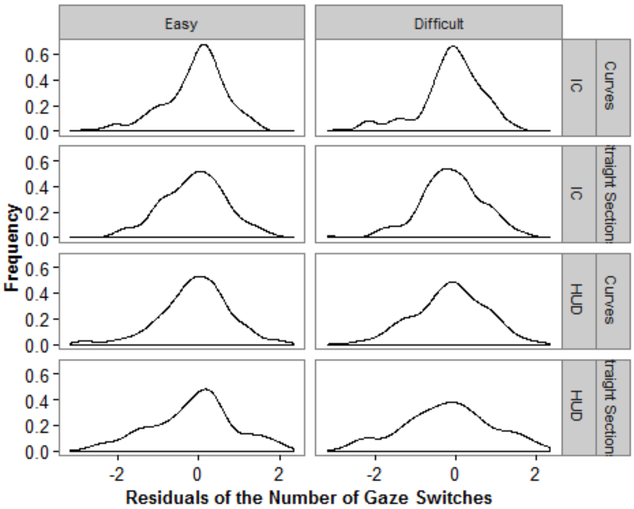


Number of Gazeswitches

```
M5 <- glmer(GazeSwitch_Target ~ Display * RoadsectionRec * SecTaskDif +
            (1|VP) + (1|Obs),
          family = poisson,
          data = D)

## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control
## $checkConv, : Model failed to converge with max|grad| = 0.00163039 (tol =
## 0.001, component 1)

summary(M5)

## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: poisson  ( log )
## Formula: GazeSwitch_Target ~ Display * RoadsectionRec * SecTaskDif + (1 |
##     VP) + (1 | Obs)
##    Data: D
##
##      AIC      BIC   logLik deviance df.resid
##   5078.1   5127.6  -2529.1   5058.1     1029
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.25105 -0.56995 -0.03494  0.43659  2.75406
##
## Random effects:
##  Groups Name        Variance Std.Dev.
##  Obs    (Intercept) 0.06291  0.2508
##  VP     (Intercept) 0.07955  0.2820
## Number of obs: 1039, groups:  Obs, 1039; VP, 24
##
## Fixed effects:
##                                                    Estimate
## (Intercept)                                        1.954545
## DisplayHUD                                        -0.180310
## RoadsectionRecStraight Sections                   -0.204759
## SecTaskDifDifficult                                0.023907
## DisplayHUD:RoadsectionRecStraight Sections        -0.035604
## DisplayHUD:SecTaskDifDifficult                    -0.190727
## RoadsectionRecStraight Sections:SecTaskDifDifficult -0.011973
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult -0.006056
##                                                    Std. Error
## (Intercept)                                          0.070695
```

```
## DisplayHUD                                                        0.058439
## RoadsectionRecStraight Sections                                   0.058535
## SecTaskDifDifficult                                               0.056070
## DisplayHUD:RoadsectionRecStraight Sections                        0.084989
## DisplayHUD:SecTaskDifDifficult                                    0.082555
## RoadsectionRecStraight Sections:SecTaskDifDifficult               0.081575
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult   0.121197
##                                                                 z value
## (Intercept)                                                      27.647
## DisplayHUD                                                       -3.085
## RoadsectionRecStraight Sections                                  -3.498
## SecTaskDifDifficult                                               0.426
## DisplayHUD:RoadsectionRecStraight Sections                       -0.419
## DisplayHUD:SecTaskDifDifficult                                   -2.310
## RoadsectionRecStraight Sections:SecTaskDifDifficult              -0.147
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult  -0.050
##                                                                 Pr(>|z|)
## (Intercept)                                                      < 2e-16
## DisplayHUD                                                      0.002032
## RoadsectionRecStraight Sections                                 0.000469
## SecTaskDifDifficult                                             0.669835
## DisplayHUD:RoadsectionRecStraight Sections                      0.675270
## DisplayHUD:SecTaskDifDifficult                                  0.020872
## RoadsectionRecStraight Sections:SecTaskDifDifficult             0.883307
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult 0.960144
##
## (Intercept)                                                     ***
## DisplayHUD                                                      **
## RoadsectionRecStraight Sections                                 ***
## SecTaskDifDifficult
## DisplayHUD:RoadsectionRecStraight Sections
## DisplayHUD:SecTaskDifDifficult                                  *
## RoadsectionRecStraight Sections:SecTaskDifDifficult
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) DspHUD RdsRSS ScTsDD DsHUD:RRSS DHUD:ST RRSS:S
## DisplayHUD  -0.401
## RdsctnRcStS -0.398  0.484
## ScTskDfDffc -0.419  0.504  0.504
## DspHUD:RRSS  0.275 -0.683 -0.688 -0.347
## DspHUD:STDD  0.286 -0.704 -0.342 -0.678  0.483
## RdsRSS:STDD  0.287 -0.345 -0.717 -0.686  0.494      0.465
## DHUD:RRSS:S -0.193  0.478  0.482  0.461 -0.701     -0.680  -0.673
## convergence code: 0
## Model failed to converge with max|grad| = 0.00163039 (tol = 0.001, component 1)

D$resid_M5 <- residuals(M5)

DrenamedM5<-D
DrenamedM5<- rename(DrenamedM5, Road_Sections = RoadsectionRec)
DrenamedM5<- rename(DrenamedM5, Display_Locations = Display)
DrenamedM5<- rename(DrenamedM5, Secondary_Task_Difficulty = SecTaskDif)

DrenamedM5 %>%
  ggplot(aes(x = resid_M5)) +
  geom_density() +
  facet_grid(Display_Locations ~ Road_Sections ~ Secondary_Task_Difficulty) +
  scale_y_continuous("Frequency") +
  scale_x_continuous("Residuals of the Number of Gaze Switches")+
  theme_bw() +
   theme(axis.title.x = element_text(family="sans", face="bold", size=10),
      axis.title.y = element_text(family="sans", face="bold", size=10, angle=90),
      axis.text.x = element_text(family="sans",  size=10),
```

```
      axis.text.y = element_text(family="sans",  size=10),
      panel.grid.major = element_line( colour = "white"),
      panel.grid.minor = element_line( colour = "white"),
      legend.title =element_text(family="sans", face = "bold", size=10),
      legend.text = element_text(family="sans",  size=8),
      strip.text.x = element_text(family="sans", size=8),
      strip.text.y = element_text(family="sans", size=8)
  )
```

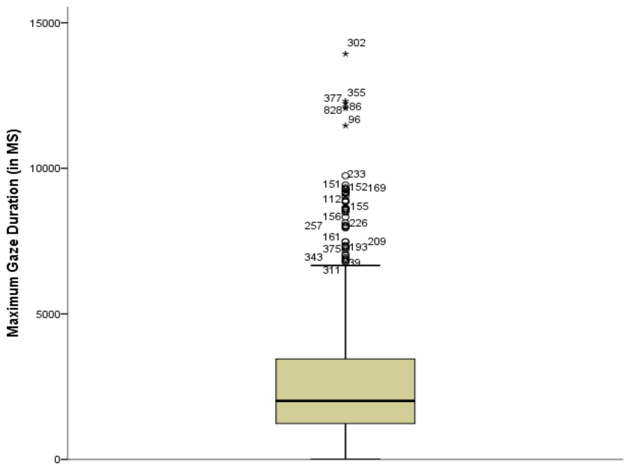


Explorative Data Analysis with SPSS

```
/*Data exploration following the protocol of Zuur et al. (2010)*/
/*Step one: Are there outliers in Y and X? (X is not applicable here)*/

DATASET ACTIVATE DataSet1.
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Max_MS_Target MISSING=LISTWISE
REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: Max_MS_Target=col(source(s). name("Max_MS_Target"))
  DATA: id=col(source(s). name("$CASENUM"). unit.category())
  GUIDE: axis(dim(2). label("Max_MS_Target"))
  ELEMENT: schema(position(bin.quantile.letter(1*Max_MS_Target)). label(id))
END GPL.
```

GGraph

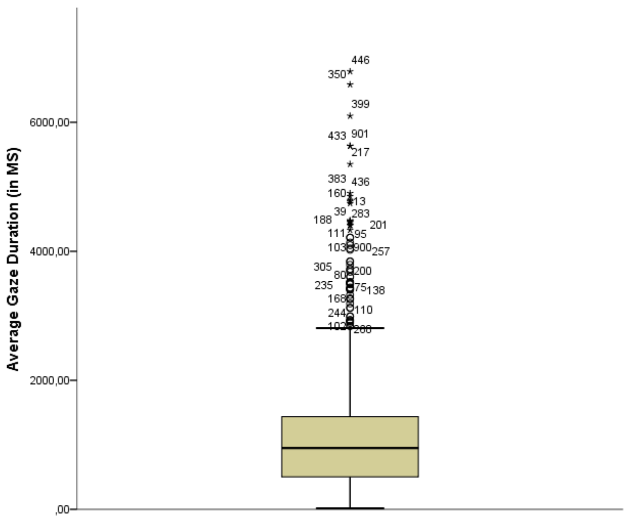
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```




```
DATASET ACTIVATE DataSet1.
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Mean_MS_Target MISSING=LISTWISE
REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: Mean_MS_Target=col(source(s), name("Mean_MS_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(2), label("Mean_MS_Target"))
  ELEMENT: schema(position(bin.quantile.letter(1*Mean_MS_Target)), label(id))
END GPL.
```

GGraph

```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```

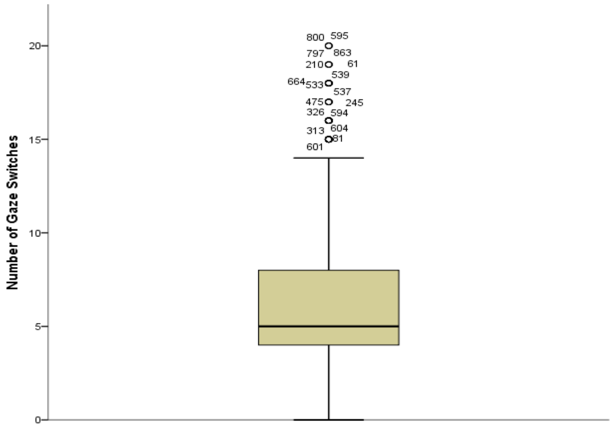



```
DATASET ACTIVATE DataSet1.
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=GazeSwitch_Target MISSING=LISTWISE
REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: GazeSwitch_Target=col(source(s), name("GazeSwitch_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(2), label("GazeSwitch_Target"))
  ELEMENT: schema(position(bin.quantile.letter(1*GazeSwitch_Target)), label(id))
```

```
END GPL.
```

GGraph

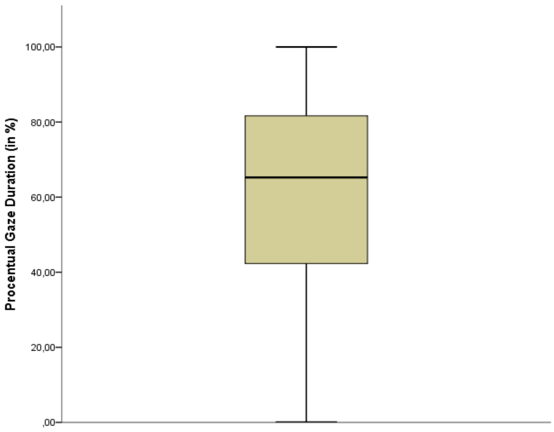
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```




```
DATASET ACTIVATE DataSet1.
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=PGD_MS_Target MISSING=LISTWISE
REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: PGD_MS_Target=col(source(s), name("PGD_MS_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(2), label("PGD_MS_Target"))
  ELEMENT: schema(position(bin.quantile.letter(1*PGD_MS_Target)), label(id))
END GPL.
```

GGraph

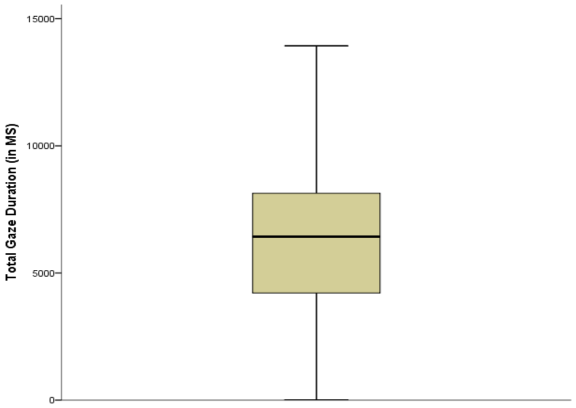
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```




```
DATASET ACTIVATE DataSet1.
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Sum_MS_Target MISSING=LISTWISE
REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: Sum_MS_Target=col(source(s), name("Sum_MS_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(2), label("Sum_MS_Target"))
  ELEMENT: schema(position(bin.quantile.letter(1*Sum_MS_Target)), label(id))
END GPL.
```

GGraph

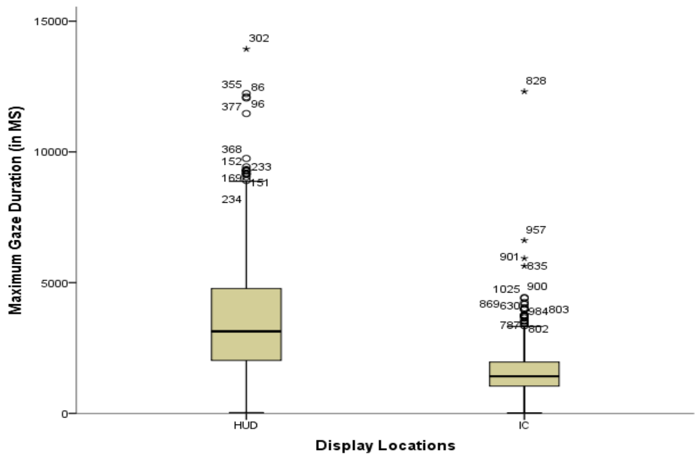
```
 [DataSet1] D:\Realfahrt\08_Data nalysis\Datensatz_SchmidtMAVW_130616_v2.sav
```




```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Display Max_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: Display=col(source(s), name("Display"), unit.category())
  DATA: Max_MS_Target=col(source(s), name("Max_MS_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(1), label("Display"))
  GUIDE: axis(dim(2), label("Max_MS_Target"))
  SCALE: cat(dim(1), include("1", "2"))
  SCALE: linear(dim(2), include(0))
  ELEMENT: schema(position(bin.quantile.letter(Display*Max_MS_Target)), label(id))
END GPL.
```

GGraph

```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```

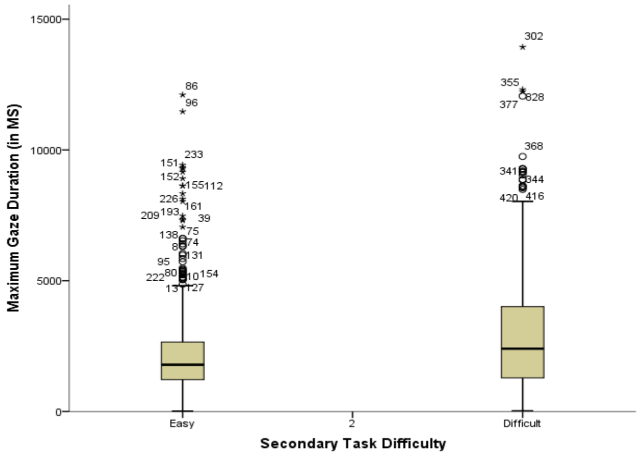



```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=SecTaskDif Max_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: SecTaskDif=col(source(s), name("SecTaskDif"), unit.category())
  DATA: Max_MS_Target=col(source(s), name("Max_MS_Target"))
```

```
  DATA: id=col(source(s). name("$CASENUM"). unit.category())
  GUIDE: axis(dim(1). label("SecTaskDif"))
  GUIDE: axis(dim(2). label("Max_MS_Target"))
  SCALE: cat(dim(1). include("1". "2"))
  SCALE: linear(dim(2). include(0))
  ELEMENT: schema(position(bin.quantile.letter(SecTaskDif*Max_MS_Target)).
label(id))
END GPL.
```

GGraph

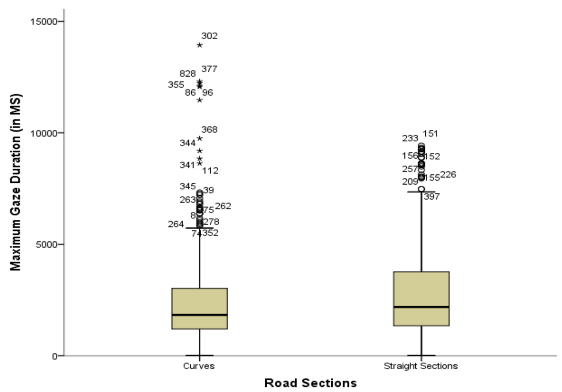
```
 [DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```




```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=RoadsectionRec Max_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: RoadsectionRec=col(source(s). name("RoadsectionRec"). unit.category())
  DATA: Max_MS_Target=col(source(s). name("Max_MS_Target"))
  DATA: id=col(source(s). name("$CASENUM"). unit.category())
  GUIDE: axis(dim(1). label("RoadsectionRec"))
  GUIDE: axis(dim(2). label("Max_MS_Target"))
  SCALE: cat(dim(1). include("1". "2"))
  SCALE: linear(dim(2). include(0))
  ELEMENT: schema(position(bin.quantile.letter(RoadsectionRec*Max_MS_Target)).
label(id))
END GPL.
```

GGraph

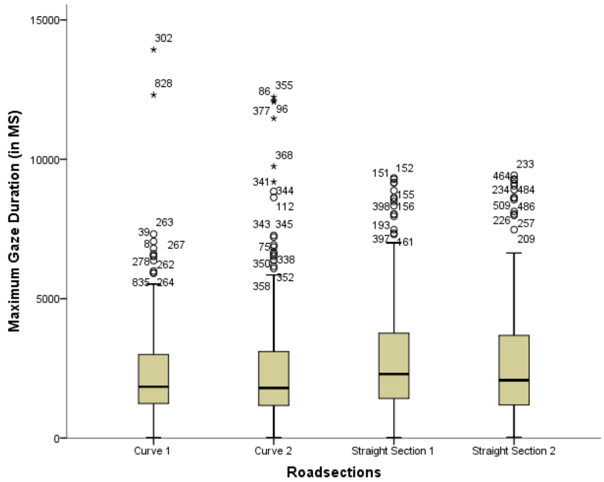
```
 [DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```



```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Roadsection Max_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: Roadsection=col(source(s). name("Roadsection"). unit.category())
  DATA: Max_MS_Target=col(source(s). name("Max_MS_Target"))
  DATA: id=col(source(s). name("$CASENUM"). unit.category())
  GUIDE: axis(dim(1). label("Roadsection"))
  GUIDE: axis(dim(2). label("Max_MS_Target"))
  SCALE: cat(dim(1). include("1". "2". "3". "4"))
  SCALE: linear(dim(2). include(0))
  ELEMENT: schema(position(bin.quantile.letter(Roadsection*Max_MS_Target)).
label(id))
END GPL.
```

GGraph

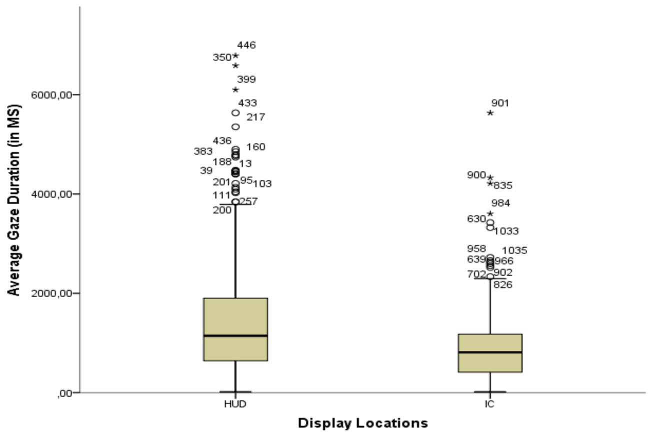
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```




```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Display Mean_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: Display=col(source(s). name("Display"). unit.category())
  DATA: Mean_MS_Target=col(source(s). name("Mean_MS_Target"))
  DATA: id=col(source(s). name("$CASENUM"). unit.category())
  GUIDE: axis(dim(1). label("Display"))
  GUIDE: axis(dim(2). label("Mean_MS_Target"))
  SCALE: cat(dim(1). include("1". "2"))
  SCALE: linear(dim(2). include(0))
  ELEMENT: schema(position(bin.quantile.letter(Display*Mean_MS_Target)). label(id))
END GPL.
```

GGraph

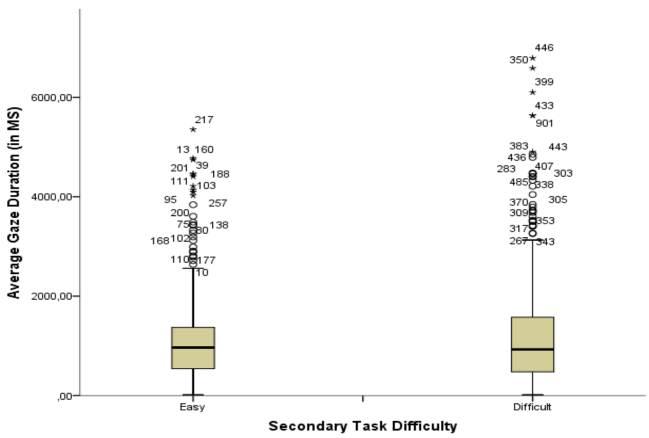
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```




```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=SecTaskDif Mean_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: SecTaskDif=col(source(s), name("SecTaskDif"), unit.category())
  DATA: Mean_MS_Target=col(source(s), name("Mean_MS_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(1), label("SecTaskDif"))
  GUIDE: axis(dim(2), label("Mean_MS_Target"))
  SCALE: cat(dim(1), include("1", "2"))
  SCALE: linear(dim(2), include(0))
  ELEMENT: schema(position(bin.quantile.letter(SecTaskDif*Mean_MS_Target)),
label(id))
END GPL.
```

GGraph

```
 [DataSet1] D:\Realfahrt\08_Data nalysis\Datensatz_SchmidtMAVW_130616_v2.sav
```

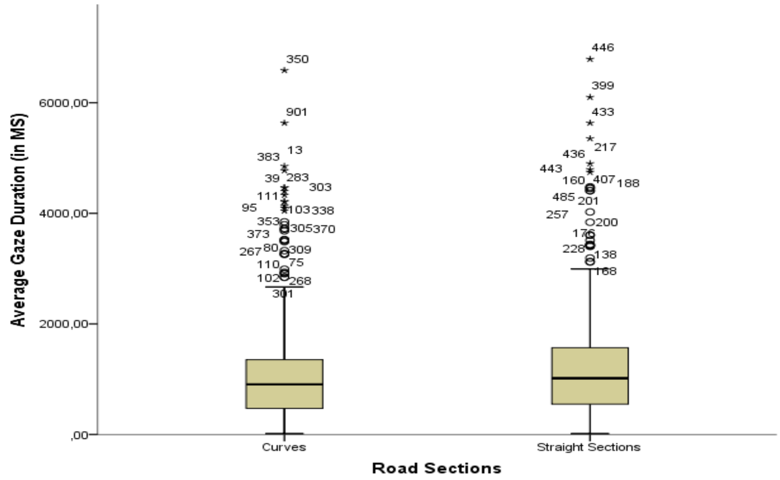



```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=RoadsectionRec Mean_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: RoadsectionRec=col(source(s), name("RoadsectionRec"), unit.category())
  DATA: Mean_MS_Target=col(source(s), name("Mean_MS_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(1), label("RoadsectionRec"))
```

```
  GUIDE: axis(dim(2), label("Mean_MS_Target"))
  SCALE: cat(dim(1), include("1", "2"))
  SCALE: linear(dim(2), include(0))
  ELEMENT: schema(position(bin.quantile.letter(RoadsectionRec*Mean_MS_Target)),
label(id))
END GPL.
```

GGraph

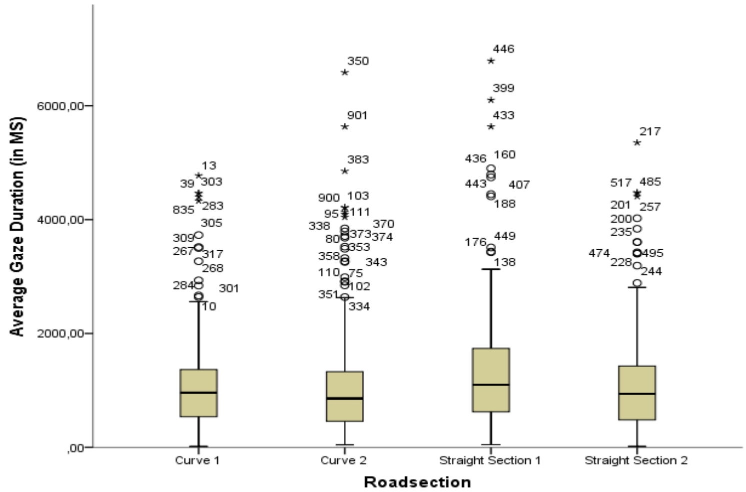
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```




```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Roadsection Mean_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: Roadsection=col(source(s), name("Roadsection"), unit.category())
  DATA: Mean_MS_Target=col(source(s), name("Mean_MS_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(1), label("Roadsection"))
  GUIDE: axis(dim(2), label("Mean_MS_Target"))
  SCALE: cat(dim(1), include("1", "2", "3", "4"))
  SCALE: linear(dim(2), include(0))
  ELEMENT: schema(position(bin.quantile.letter(Roadsection*Mean_MS_Target)),
label(id))
END GPL.
```

GGraph

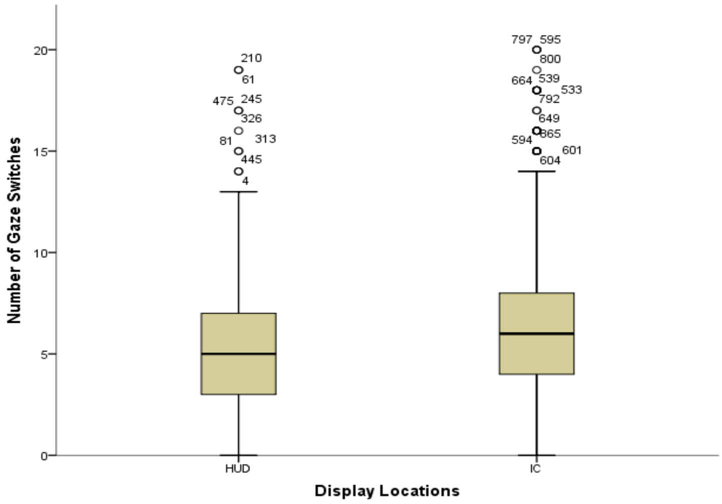
```
[DataSet1] D:\Realfahrt\08_DataAnalysis\Datensatz_SchmidtMAVW_130616_v2.sav
```



```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Display GazeSwitch_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: Display=col(source(s), name("Display"), unit.category())
  DATA: GazeSwitch_Target=col(source(s), name("GazeSwitch_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(1), label("Display"))
  GUIDE: axis(dim(2), label("GazeSwitch_Target"))
  SCALE: cat(dim(1), include("1", "2"))
  SCALE: linear(dim(2), include(0))
  ELEMENT: schema(position(bin.quantile.letter(Display*GazeSwitch_Target)),
label(id))
END GPL.
```

GGraph

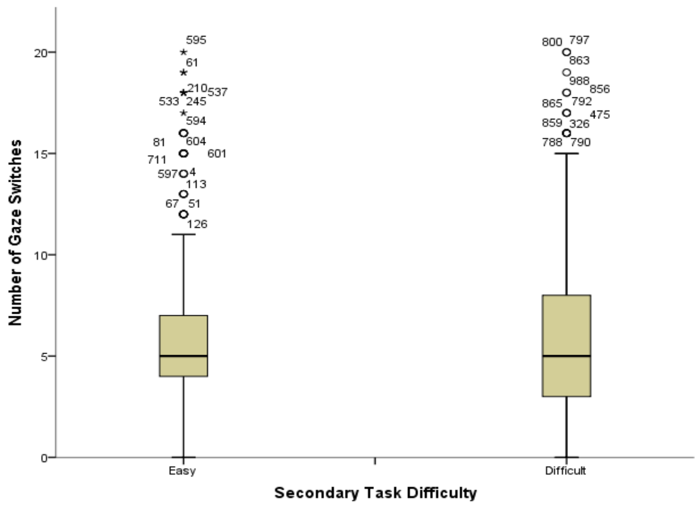
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav




```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=SecTaskDif GazeSwitch_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: SecTaskDif=col(source(s), name("SecTaskDif"), unit.category())
  DATA: GazeSwitch_Target=col(source(s), name("GazeSwitch_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(1), label("SecTaskDif"))
  GUIDE: axis(dim(2), label("GazeSwitch_Target"))
  SCALE: cat(dim(1), include("1", "2"))
  SCALE: linear(dim(2), include(0))
  ELEMENT: schema(position(bin.quantile.letter(SecTaskDif*GazeSwitch_Target)),
label(id))
END GPL.
```

GGraph

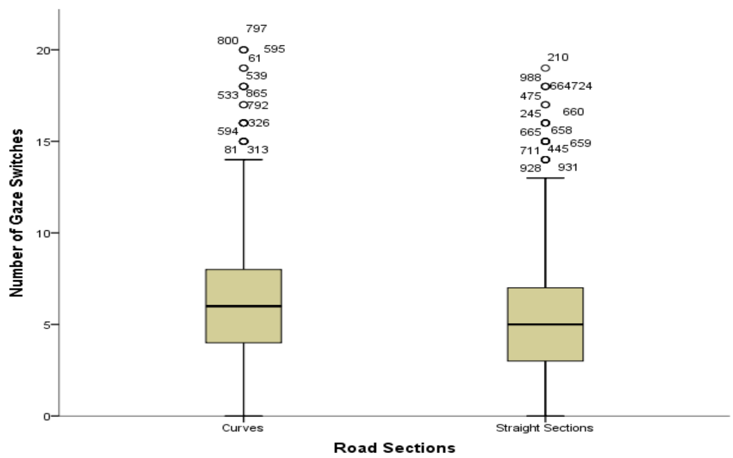
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav




```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=RoadsectionRec GazeSwitch_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: RoadsectionRec=col(source(s). name("RoadsectionRec"). unit.category())
  DATA: GazeSwitch_Target=col(source(s). name("GazeSwitch_Target"))
  DATA: id=col(source(s). name("$CASENUM"). unit.category())
  GUIDE: axis(dim(1). label("RoadsectionRec"))
  GUIDE: axis(dim(2). label("GazeSwitch_Target"))
  SCALE: cat(dim(1). include("1". "2"))
  SCALE: linear(dim(2). include(0))
  ELEMENT: schema(position(bin.quantile.letter(RoadsectionRec*GazeSwitch_Target)).
label(id))
END GPL.
```

GGraph

```
[DataSet1] D:\Realfahrt\08_DataAnalysis\Datensatz_SchmidtMAVW_130616_v2.sav
```

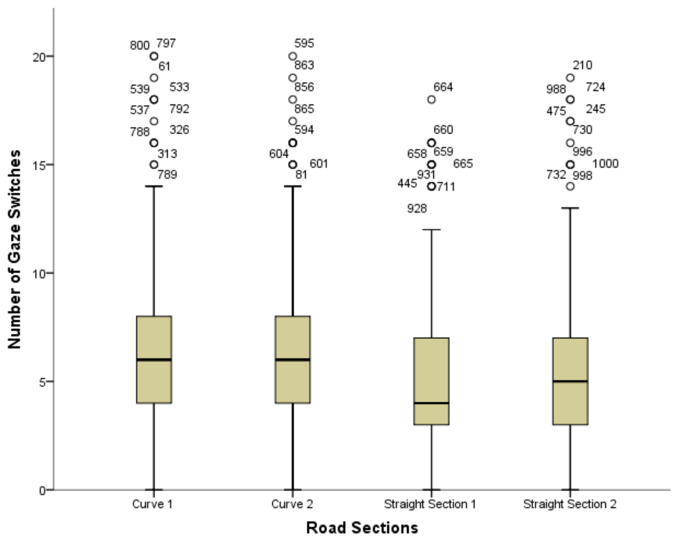



```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Roadsection GazeSwitch_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
```

```
  DATA: Roadsection=col(source(s). name("Roadsection"). unit.category())
  DATA: GazeSwitch_Target=col(source(s). name("GazeSwitch_Target"))
  DATA: id=col(source(s). name("$CASENUM"). unit.category())
  GUIDE: axis(dim(1). label("Roadsection"))
  GUIDE: axis(dim(2). label("GazeSwitch_Target"))
  SCALE: cat(dim(1). include("1". "2". "3". "4"))
  SCALE: linear(dim(2). include(0))
  ELEMENT: schema(position(bin.quantile.letter(Roadsection*GazeSwitch_Target)).
label(id))
END GPL.
```

GGraph

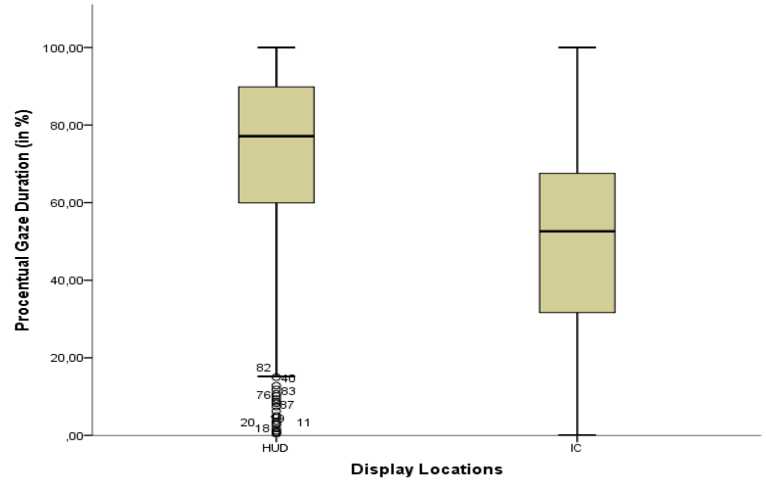
```
 [DataSet1] D:\Realfahrt\08_Data nalysis\Datensatz_SchmidtMAVW_130616_v2.sav
```




```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Display PGD_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: Display=col(source(s). name("Display"). unit.category())
  DATA: PGD_MS_Target=col(source(s). name("PGD_MS_Target"))
  DATA: id=col(source(s). name("$CASENUM"). unit.category())
  GUIDE: axis(dim(1). label("Display"))
  GUIDE: axis(dim(2). label("PGD_MS_Target"))
  SCALE: cat(dim(1). include("1". "2"))
  SCALE: linear(dim(2). include(0))
  ELEMENT: schema(position(bin.quantile.letter(Display*PGD_MS_Target)). label(id))
END GPL.
```

GGraph

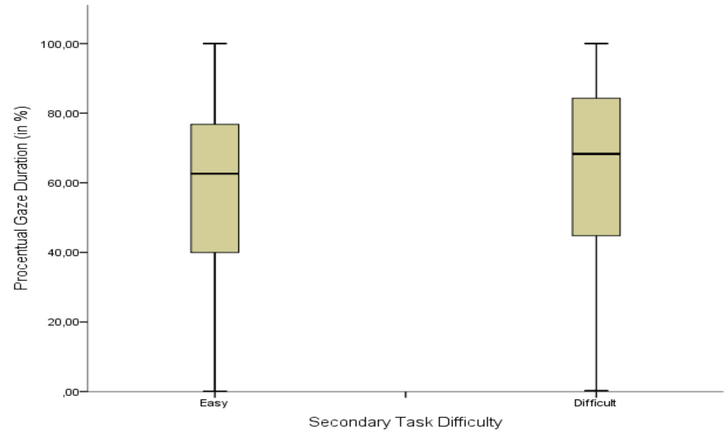
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```




```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=SecTaskDif PGD_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: SecTaskDif=col(source(s). name("SecTaskDif"). unit.category())
  DATA: PGD_MS_Target=col(source(s). name("PGD_MS_Target"))
  DATA: id=col(source(s). name("$CASENUM"). unit.category())
  GUIDE: axis(dim(1). label("SecTaskDif"))
  GUIDE: axis(dim(2). label("PGD_MS_Target"))
  SCALE: cat(dim(1). include("1". "2"))
  SCALE: linear(dim(2). include(0))
  ELEMENT: schema(position(bin.quantile.letter(SecTaskDif*PGD_MS_Target)).
label(id))
END GPL.
```

GGraph

```
 [DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```

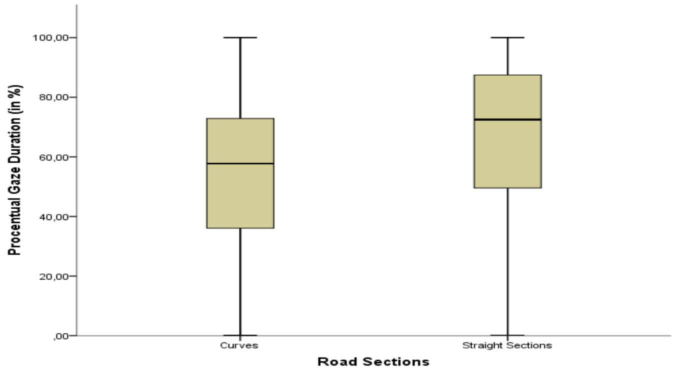



```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=RoadsectionRec PGD_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: RoadsectionRec=col(source(s). name("RoadsectionRec"). unit.category())
  DATA: PGD_MS_Target=col(source(s). name("PGD_MS_Target"))
  DATA: id=col(source(s). name("$CASENUM"). unit.category())
```

```
  GUIDE: axis(dim(1), label("RoadsectionRec"))
  GUIDE: axis(dim(2), label("PGD_MS_Target"))
  SCALE: cat(dim(1), include("1", "2"))
  SCALE: linear(dim(2), include(0))
  ELEMENT: schema(position(bin.quantile.letter(RoadsectionRec*PGD_MS_Target)),
label(id))
END GPL.
```

GGraph

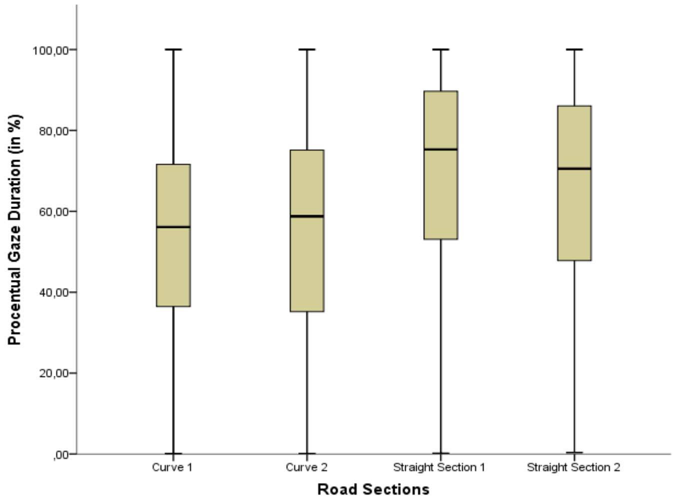
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav




```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Roadsection PGD_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: Roadsection=col(source(s), name("Roadsection"), unit.category())
  DATA: PGD_MS_Target=col(source(s), name("PGD_MS_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(1), label("Roadsection"))
  GUIDE: axis(dim(2), label("PGD_MS_Target"))
  SCALE: cat(dim(1), include("1", "2", "3", "4"))
  SCALE: linear(dim(2), include(0))
  ELEMENT: schema(position(bin.quantile.letter(Roadsection*PGD_MS_Target)),
label(id))
END GPL.
```

GGraph

[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav

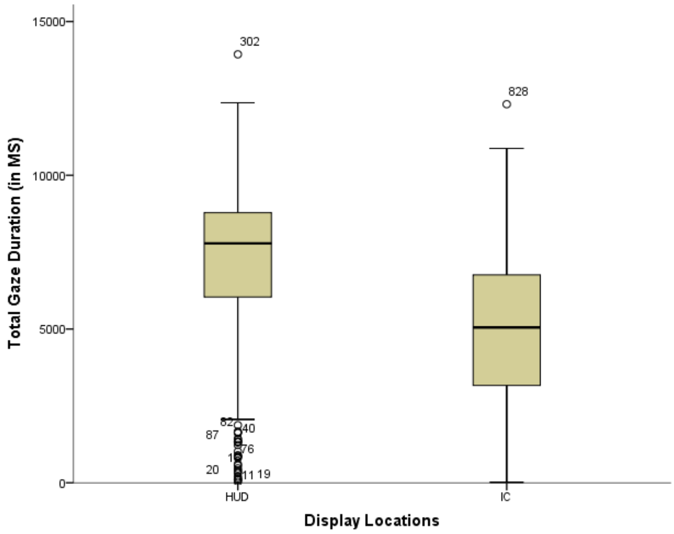



```
* Chart Builder.
GGRAPH
```

```
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Display Sum_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: Display=col(source(s), name("Display"), unit.category())
  DATA: Sum_MS_Target=col(source(s), name("Sum_MS_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(1), label("Display"))
  GUIDE: axis(dim(2), label("Sum_MS_Target"))
  SCALE: cat(dim(1), include("1", "2"))
  SCALE: linear(dim(2), include(0))
  ELEMENT: schema(position(bin.quantile.letter(Display*Sum_MS_Target)), label(id))
END GPL.
```

GGraph

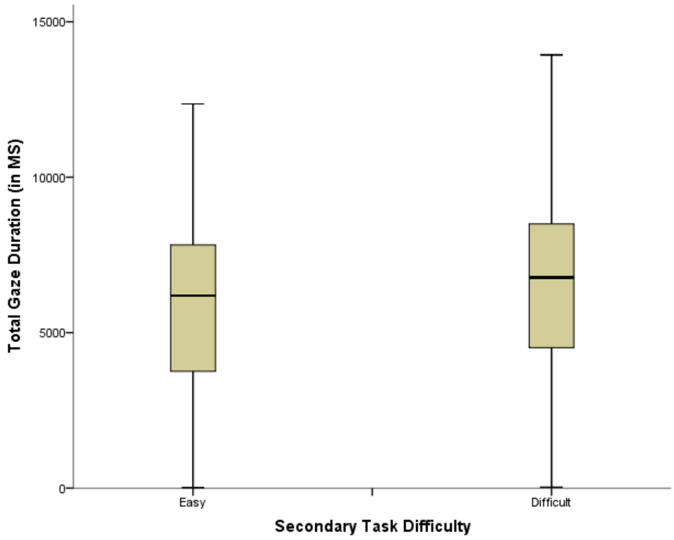
```
 [DataSet1] D:\Realfahrt\08_Datanalysis\Datensatz_SchmidtMAVW_130616_v2.sav
```




```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=SecTaskDif Sum_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: SecTaskDif=col(source(s), name("SecTaskDif"), unit.category())
  DATA: Sum_MS_Target=col(source(s), name("Sum_MS_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(1), label("SecTaskDif"))
  GUIDE: axis(dim(2), label("Sum_MS_Target"))
  SCALE: cat(dim(1), include("1", "2"))
  SCALE: linear(dim(2), include(0))
  ELEMENT: schema(position(bin.quantile.letter(SecTaskDif*Sum_MS_Target)),
label(id))
END GPL.
```

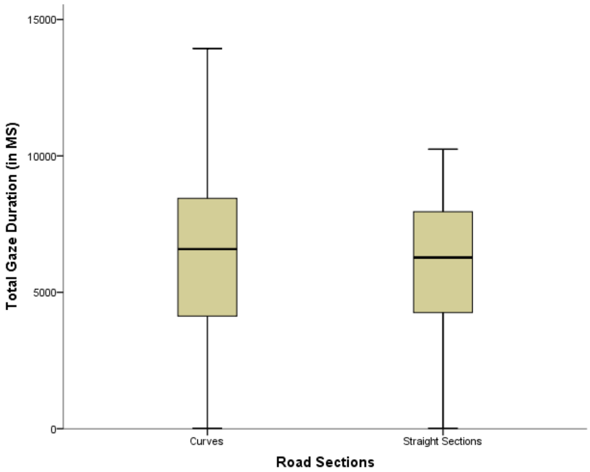
GGraph

```
 [DataSet1] D:\Realfahrt\08_Datanalysis\Datensatz_SchmidtMAVW_130616_v2.sav
```




```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=RoadsectionRec Sum_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: RoadsectionRec=col(source(s), name("RoadsectionRec"), unit.category())
  DATA: Sum_MS_Target=col(source(s), name("Sum_MS_Target"))
  DATA: id=col(source(s), name("$CASENUM"), unit.category())
  GUIDE: axis(dim(1), label("RoadsectionRec"))
  GUIDE: axis(dim(2), label("Sum_MS_Target"))
  SCALE: cat(dim(1), include("1", "2"))
  SCALE: linear(dim(2), include(0))
  ELEMENT: schema(position(bin.quantile.letter(RoadsectionRec*Sum_MS_Target)),
label(id))
END GPL.
```

GGraph
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav

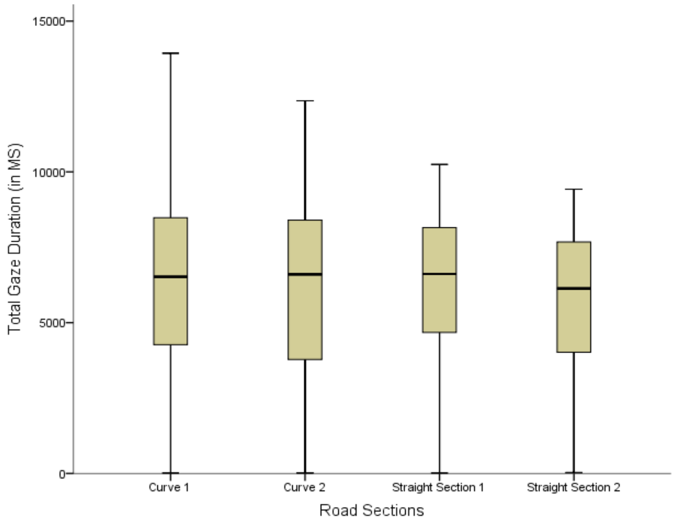



```
* Chart Builder.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Roadsection Sum_MS_Target
MISSING=LISTWISE
    REPORTMISSING=NO
```

```
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: Roadsection=col(source(s). name("Roadsection"). unit.category())
  DATA: Sum_MS_Target=col(source(s). name("Sum_MS_Target"))
  DATA: id=col(source(s). name("$CASENUM"). unit.category())
  GUIDE: axis(dim(1). label("Roadsection"))
  GUIDE: axis(dim(2). label("Sum_MS_Target"))
  SCALE: cat(dim(1). include("1". "2". "3". "4"))
  SCALE: linear(dim(2). include(0))
  ELEMENT: schema(position(bin.quantile.letter(Roadsection*Sum_MS_Target)).
label(id))
END GPL.
```

GGraph

```
[DataSet1] D:\Realfahrt\08_DataAnalysis\Datensatz_SchmidtMAVW_130616_v2.sav
```




```
EXAMINE VARIABLES=Mean_MS_Target BY SecTaskDif BY Display
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL.
```

Explore

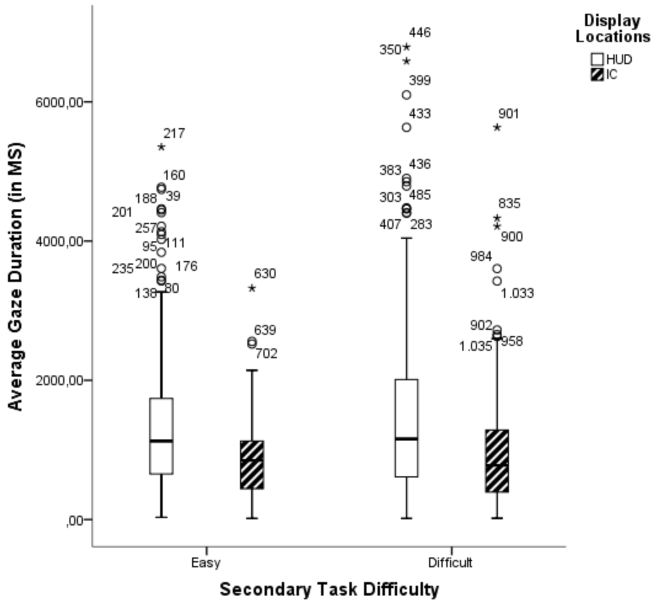
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```

Secondary Task Difficulty x Display Position

Case Processing Summary

			Cases					
			Valid		Missing		Total	
	SecTaskDif	Display	*N*	*Percent*	*N*	*Percent*	*N*	*Percent*
Average Gaze Duration (in ms)	Easy	HUD	245	93.9%	16	6.1%	261	100.0%
		IC	251	98.4%	4	1.6%	255	100.0%
	Difficult	HUD	232	86.6%	36	13.4%	268	100.0%
		IC	258	96.3%	10	3.7%	268	100.0%

Average Gaze Duration (in ms)




```
EXAMINE VARIABLES=Max_MS_Target BY SecTaskDif BY Display
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL.
```

Explore

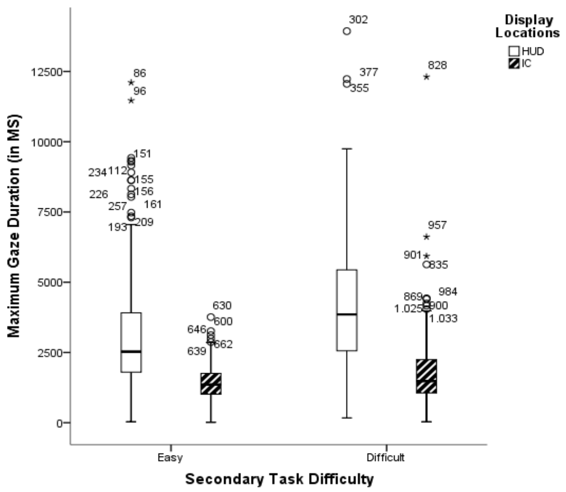
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```

Secondary Task Difficulty x Display Position

Case Processing Summary

			Cases					
			Valid		*Missing*		*Total*	
	SecTaskDif	Display	*N*	*Percent*	*N*	*Percent*	*N*	*Percent*
Maximum Gaze Duration (in ms)	Easy	HUD	261	100.0%	0	0.0%	261	100.0%
		IC	253	99.2%	2	0.8%	255	100.0%
	Difficult	HUD	264	98.5%	4	1.5%	268	100.0%
		IC	261	97.4%	7	2.6%	268	100.0%

Maximum Gaze Duration (in ms)



```
EXAMINE VARIABLES=GazeSwitch_Target BY SecTaskDif BY Display
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL.
```

Explore

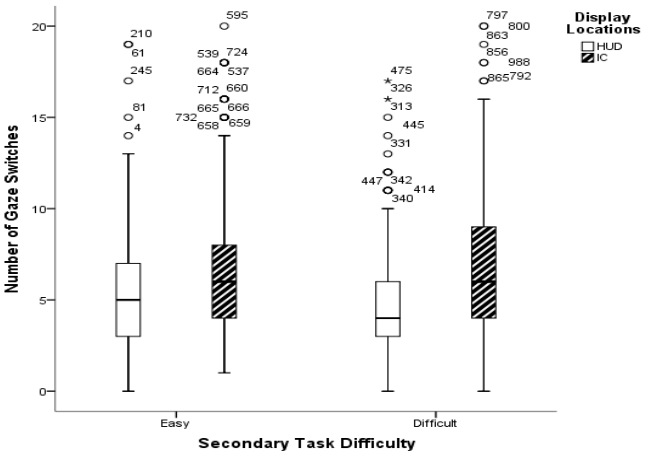
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```

Secondary Task Difficulty x Display Position

Case Processing Summary

			Cases					
			Valid		*Missing*		*Total*	
	SecTaskDif	Display	*N*	*Percent*	*N*	*Percent*	*N*	*Percent*
Number of Gaze Switches	Easy	HUD	261	100.0%	0	0.0%	261	100.0%
		IC	253	99.2%	2	0.8%	255	100.0%
	Difficult	HUD	264	98.5%	4	1.5%	268	100.0%
		IC	261	97.4%	7	2.6%	268	100.0%

Number of Gaze Switches




```
EXAMINE VARIABLES=PGD_MS_Target BY SecTaskDif BY Display
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL.
```

Explore

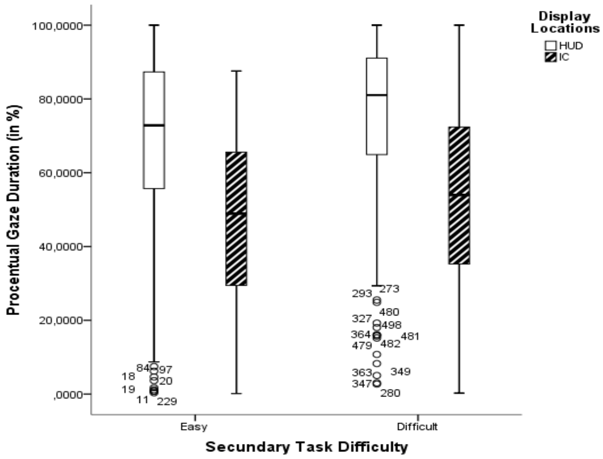
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```

Secondary Task Difficulty x Display Position

Case Processing Summary

			Cases					
			Valid		*Missing*		*Total*	
	SecTaskDif	Display	*N*	*Percent*	*N*	*Percent*	*N*	*Percent*
Gaze Percentage (in %)	Easy	HUD	261	100.0%	0	0.0%	261	100.0%
		IC	253	99.2%	2	0.8%	255	100.0%
	Difficult	HUD	264	98.5%	4	1.5%	268	100.0%
		IC	261	97.4%	7	2.6%	268	100.0%

Gaze Percentage (in %)




```
EXAMINE VARIABLES=Mean_MS_Target BY Roadsection BY Display
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL.
```

Explore

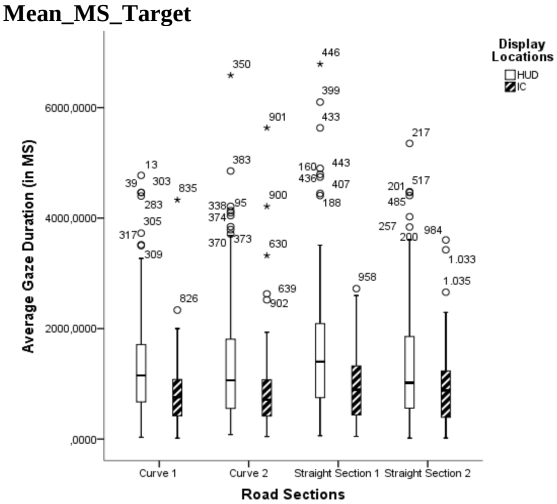
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```

Road Section x Display

Case Processing Summary

			Cases					
			Valid		*Missing*		*Total*	
	Roadsection	Display	*N*	*Percent*	*N*	*Percent*	*N*	*Percent*
Average Gaze Duration (in ms)	Curve 1	HUD	129	96.3%	5	3.7%	134	100.0%
		IC	122	96.1%	5	3.9%	127	100.0%
	Curve 2	HUD	119	91.5%	11	8.5%	130	100.0%
		IC	131	98.5%	2	1.5%	133	100.0%
	Straight Section 1	HUD	113	85.0%	20	15.0%	133	100.0%
		IC	122	95.3%	6	4.7%	128	100.0%
	Straight Section 2	HUD	116	87.9%	16	12.1%	132	100.0%
		IC	134	99.3%	1	0.7%	135	100.0%

Mean_MS_Target



```
EXAMINE VARIABLES=Max_MS_Target BY Roadsection BY Display
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL.
```

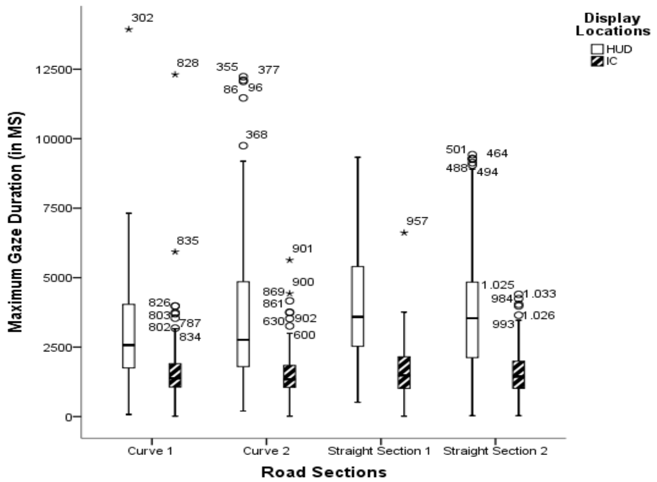
Explore
`[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav`

Road Section x Display

Case Processing Summary

			Cases					
			Valid		*Missing*		*Total*	
	Roadsection	Display	*N*	*Percent*	*N*	*Percent*	*N*	*Percent*
Maximum Gaze Duration (in ms)	Curve 1	HUD	132	98.5%	2	1.5%	134	100.0%
		IC	123	96.9%	4	3.1%	127	100.0%
	Curve 2	HUD	129	99.2%	1	0.8%	130	100.0%
		IC	132	99.2%	1	0.8%	133	100.0%
	Straight Section 1	HUD	133	100.0%	0	0.0%	133	100.0%
		IC	125	97.7%	3	2.3%	128	100.0%
	Straight Section 2	HUD	131	99.2%	1	0.8%	132	100.0%
		IC	134	99.3%	1	0.7%	135	100.0%

Maximum Gaze Duration (in ms)




```
EXAMINE VARIABLES=GazeSwitch_Target BY Roadsection BY Display
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL.
```

Explore
`[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav`

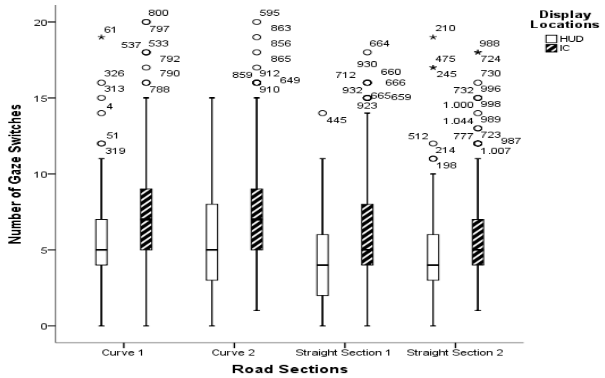
Road Section x Display

Case Processing Summary

		Cases		
Roadsection	Display	*Valid*	*Missing*	*Total*

			N	*Percent*	*N*	*Percent*	*N*	*Percent*
Number of Gaze Switches	Curve 1	HUD	132	98.5%	2	1.5%	134	100.0%
		IC	123	96.9%	4	3.1%	127	100.0%
	Curve 2	HUD	129	99.2%	1	0.8%	130	100.0%
		IC	132	99.2%	1	0.8%	133	100.0%
	Straight Section 1	HUD	133	100.0%	0	0.0%	133	100.0%
		IC	125	97.7%	3	2.3%	128	100.0%
	Straight Section 2	HUD	131	99.2%	1	0.8%	132	100.0%
		IC	134	99.3%	1	0.7%	135	100.0%

Number of Gaze Switches




```
EXAMINE VARIABLES=PGD_MS_Target BY Roadsection BY Display
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL.
```

Explore

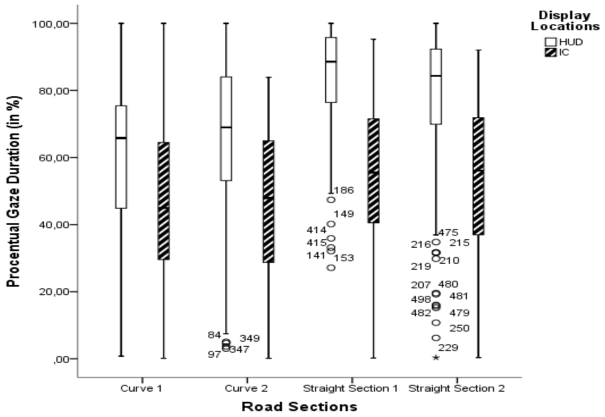
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```

Road Section x Display

Case Processing Summary

			Cases					
			Valid		*Missing*		*Total*	
	Roadsection	Display	*N*	*Percent*	*N*	*Percent*	*N*	*Percent*
Gaze Percentage (in %)	Curve 1	HUD	132	98.5%	2	1.5%	134	100.0%
		IC	123	96.9%	4	3.1%	127	100.0%
	Curve 2	HUD	129	99.2%	1	0.8%	130	100.0%
		IC	132	99.2%	1	0.8%	133	100.0%
	Straight Section 1	HUD	133	100.0%	0	0.0%	133	100.0%
		IC	125	97.7%	3	2.3%	128	100.0%
	Straight Section 2	HUD	131	99.2%	1	0.8%	132	100.0%
		IC	134	99.3%	1	0.7%	135	100.0%

Gaze Percentage (in %)




```
EXAMINE VARIABLES=Mean_MS_Target BY RoadsectionRec BY Display
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL.
```

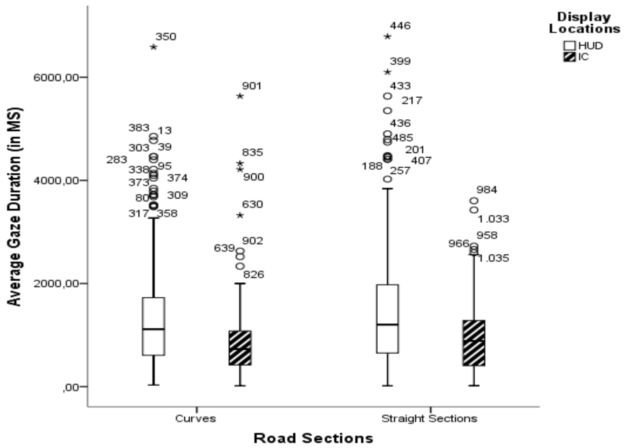
Explore
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav

Road Section Recorded x Display

Case Processing Summary

			Cases					
			Valid		*Missing*		*Total*	
	RoadsectionRec	Display	*N*	*Percent*	*N*	*Percent*	*N*	*Percent*
Average Gaze Duration (in ms)	Curves	HUD	248	93.9%	16	6.1%	264	100.0%
		IC	253	97.3%	7	2.7%	260	100.0%
	Straight Sections	HUD	229	86.4%	36	13.6%	265	100.0%
		IC	256	97.3%	7	2.7%	263	100.0%

Average Gaze Duration (in ms)




```
EXAMINE VARIABLES=Max_MS_Target BY RoadsectionRec BY Display
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL.
```

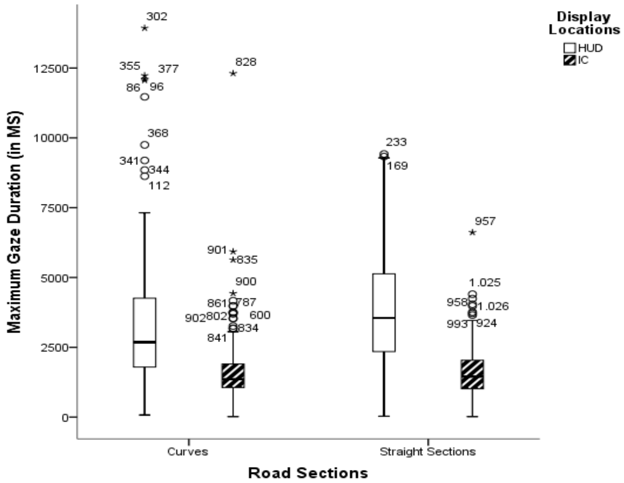
Explore
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav

Road Section Recorded x Display

Case Processing Summary

			Cases					
			Valid		*Missing*		*Total*	
	RoadsectionRec	Display	*N*	*Percent*	*N*	*Percent*	*N*	*Percent*
Maximum Gaze Duration (in ms)	Curves	HUD	261	98.9%	3	1.1%	264	100.0%
		IC	255	98.1%	5	1.9%	260	100.0%
	Straight Sections	HUD	264	99.6%	1	0.4%	265	100.0%
		IC	259	98.5%	4	1.5%	263	100.0%

Maximum Gaze Duration (in ms)




```
EXAMINE VARIABLES=GazeSwitch_Target BY RoadsectionRec BY Display
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL.
```

Explore

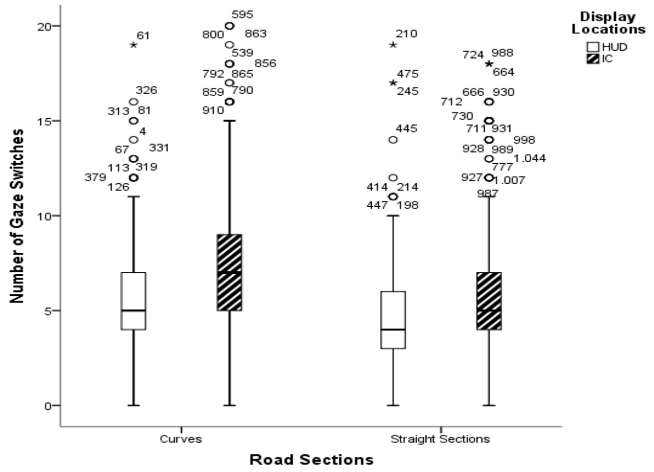
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```

Road Section Recorded x Display

Case Processing Summary

			Cases					
			Valid		*Missing*		*Total*	
	RoadsectionRec	Display	*N*	*Percent*	*N*	*Percent*	*N*	*Percent*
Number of Gaze Switches	Curves	HUD	261	98.9%	3	1.1%	264	100.0%
		IC	255	98.1%	5	1.9%	260	100.0%
	Straight Sections	HUD	264	99.6%	1	0.4%	265	100.0%
		IC	259	98.5%	4	1.5%	263	100.0%

Number of Gaze Switches




```
EXAMINE VARIABLES=PGD_MS_Target BY RoadsectionRec BY Display
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL.
```

Explore

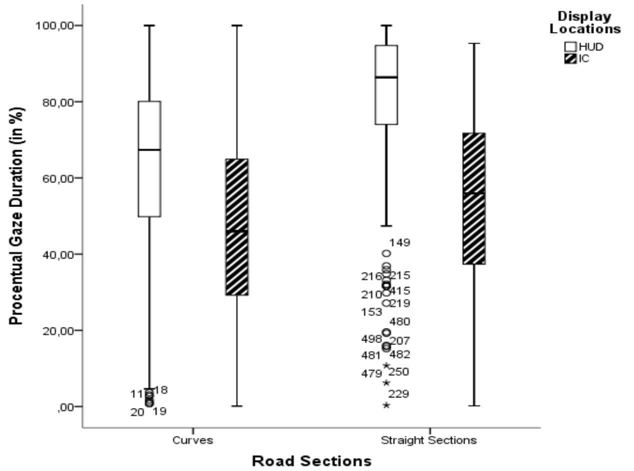
```
[DataSet1] D:\Realfahrt\08_Data Analysis\Datensatz_SchmidtMAVW_130616_v2.sav
```

Road Section Recorded x Display

Case Processing Summary

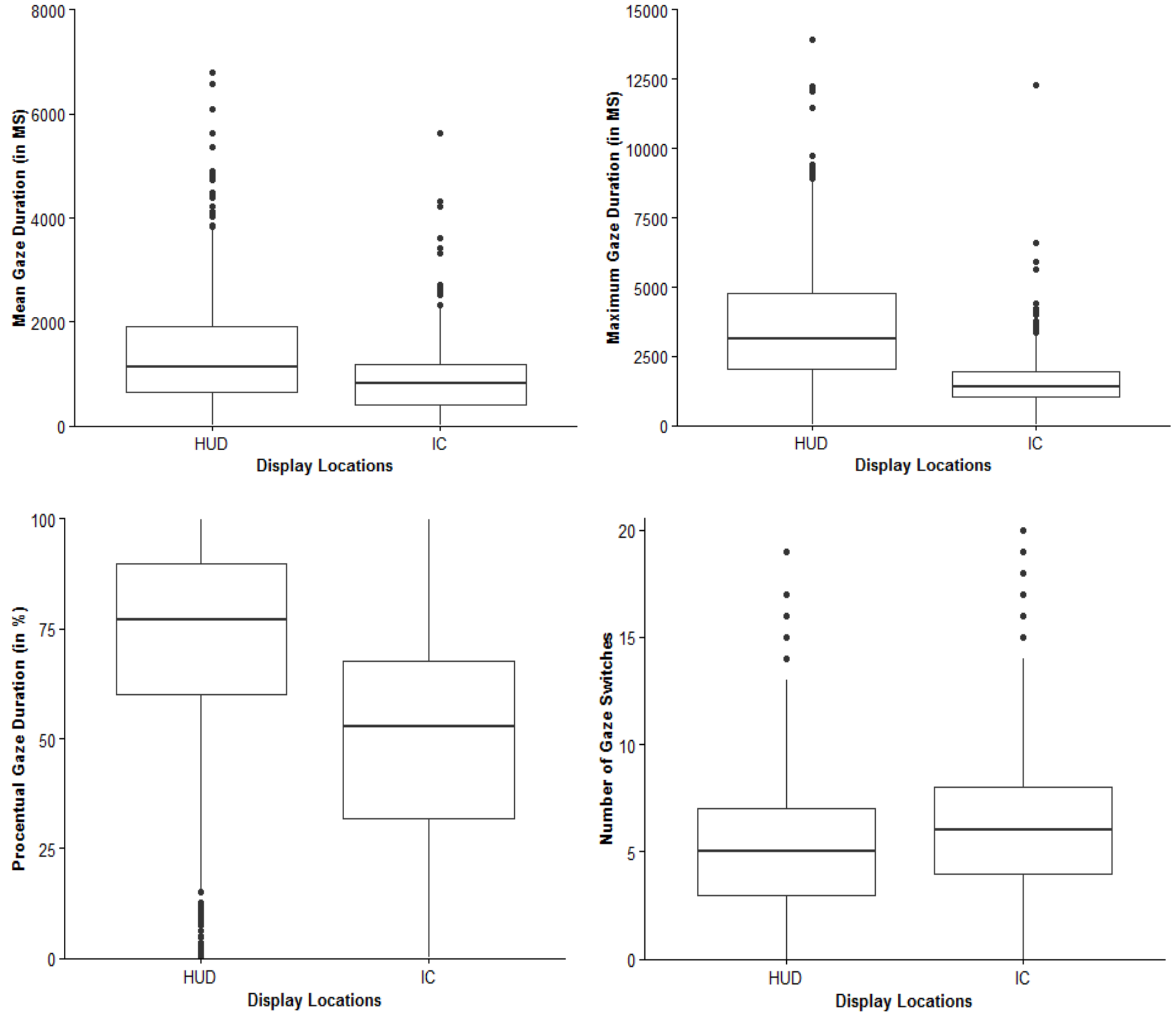
			Cases					
			Valid		*Missing*		*Total*	
	RoadsectionRec	Display	*N*	*Percent*	*N*	*Percent*	*N*	*Percent*
Gaze Percentage (in %)	Curves	HUD	261	98.9%	3	1.1%	264	100.0%
		IC	255	98.1%	5	1.9%	260	100.0%
	Straight Sections	HUD	264	99.6%	1	0.4%	265	100.0%
		IC	259	98.5%	4	1.5%	263	100.0%

Gaze Percentage (in %)

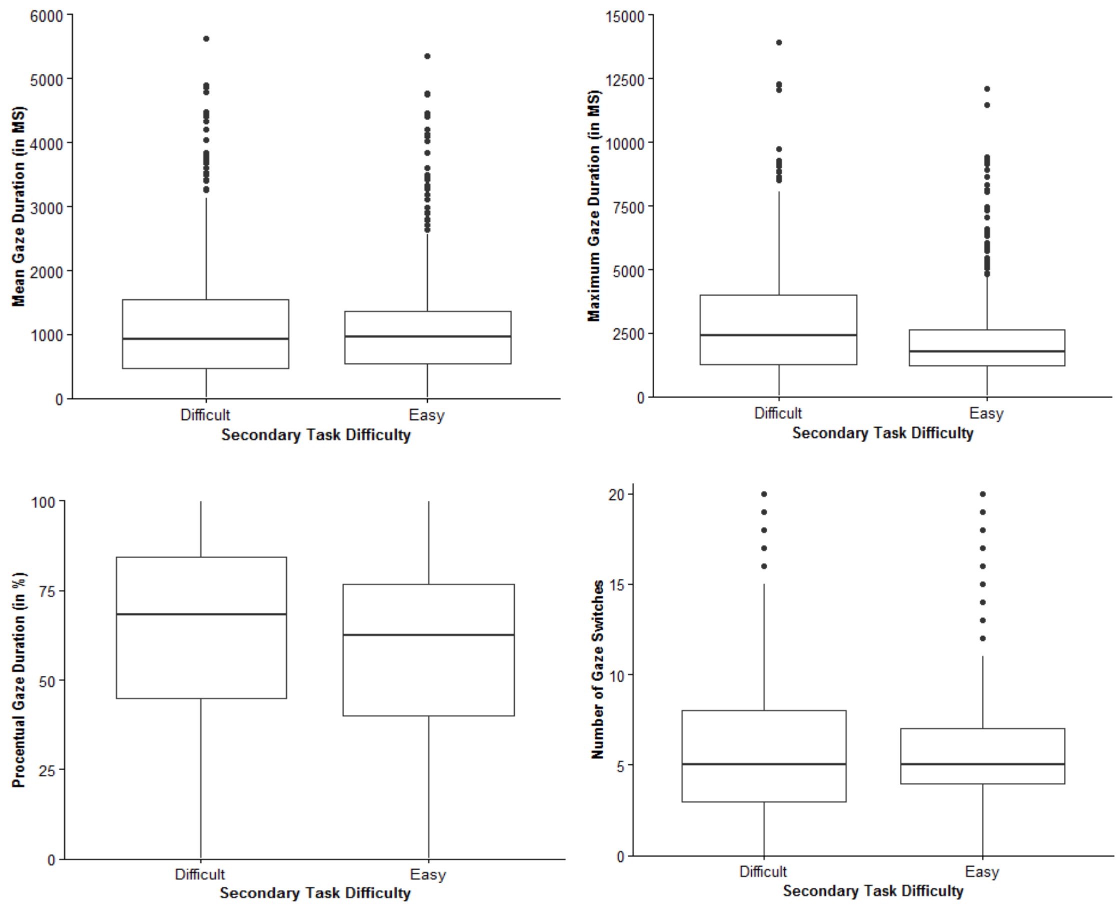


Plotting the Dependent Variables (with examplarix R codes for each plot variant)

```
#Plots on the Group level
#Display_Locations comparison
Disp_Mean<-ggplot(Dataframeclean, aes(Display_Locations, Mean_MS_Target))
Disp_Mean +
  geom_boxplot() +
  scale_y_continuous( "Mean Gaze Duration (in MS)", limits = c(0,8000), breaks = seq( 0,
8000, by = 2000), expand = c(0,0)) +
  scale_x_discrete( "Display Locations")+
  theme_bw () +
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 10),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 10),
        legend.text = element_text (family = "sans", size = 10),
        strip.text.x = element_text (family = "sans", size = 10)
        )

## Warning: Removed 66 rows containing non-finite values (stat_boxplot).
```

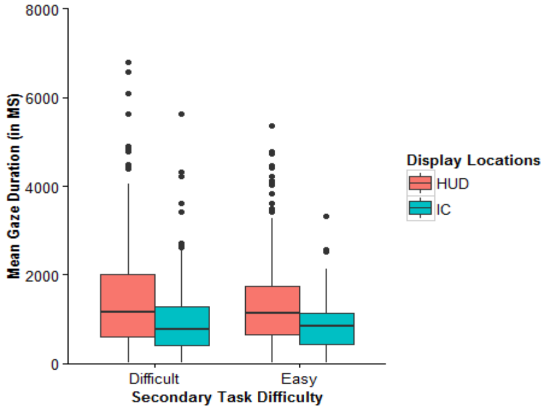


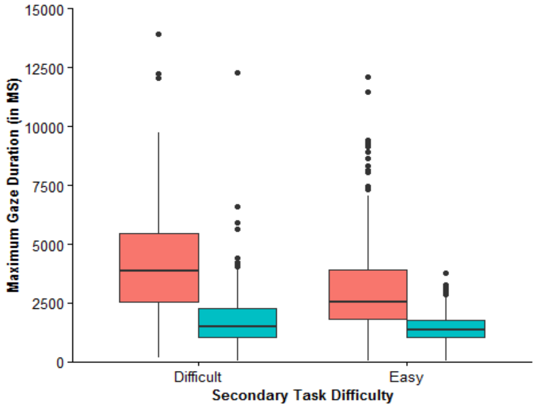
```
#Tasklevel comparison
#All Display_Locations combined
SecTaskDiff_Mean<-ggplot(Dataframeclean, aes(Secondary_Task_Difficulty, Mean_MS_Target))
SecTaskDiff_Mean + geom_boxplot() +
  scale_y_continuous( "Mean Gaze Duration (in MS)", limits = c(0,6000), breaks = seq( 0,
6000, by = 1000), expand = c(0,0)) +
  scale_x_discrete( "Secondary Task Difficulty") +
  theme_bw () +
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 10),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 10),
        legend.text = element_text (family = "sans", size = 10),
        strip.text.x = element_text (family = "sans", size = 10)
        )

## Warning: Removed 69 rows containing non-finite values (stat_boxplot).
```

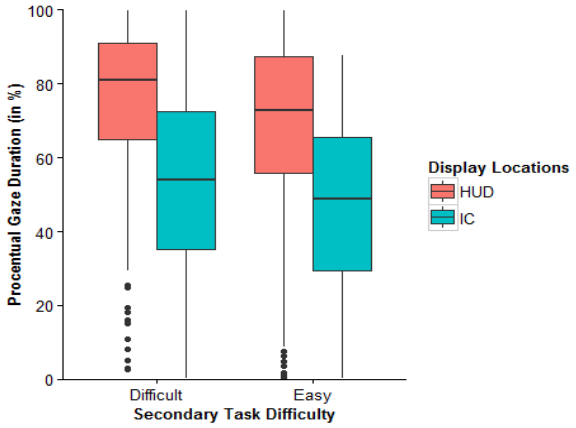


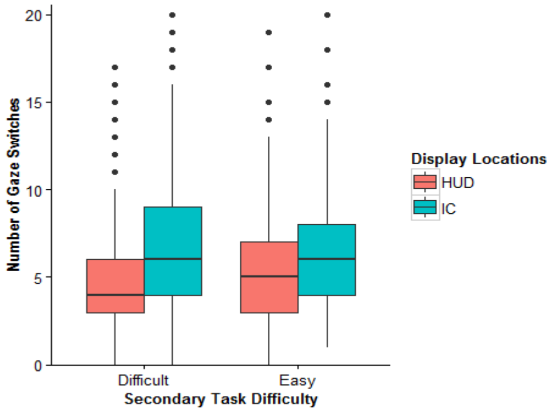

```
#Tasklevel - Separate for the Display_Locations
SecTaskDiff_Mean<-ggplot(Dataframeclean, aes(Secondary_Task_Difficulty, Mean_MS_Target,
fill = Display))
SecTaskDiff_Mean + geom_boxplot() +
  scale_y_continuous( "Mean Gaze Duration (in MS)", limits = c(0,8000), breaks = seq( 0,
8000, by = 2000), expand = c(0,0)) +
  scale_x_discrete( "Secondary Task Difficulty") +
  scale_fill_discrete (name = "Display Locations", breaks = c ("1", "2"), labels = c("HUD",
"IC")) +
```

```
  theme_bw () +
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 10),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 10),
        legend.text = element_text (family = "sans", size = 10),
        strip.text.x = element_text (family = "sans", size = 10)
        )

## Warning: Removed 66 rows containing non-finite values (stat_boxplot).
```



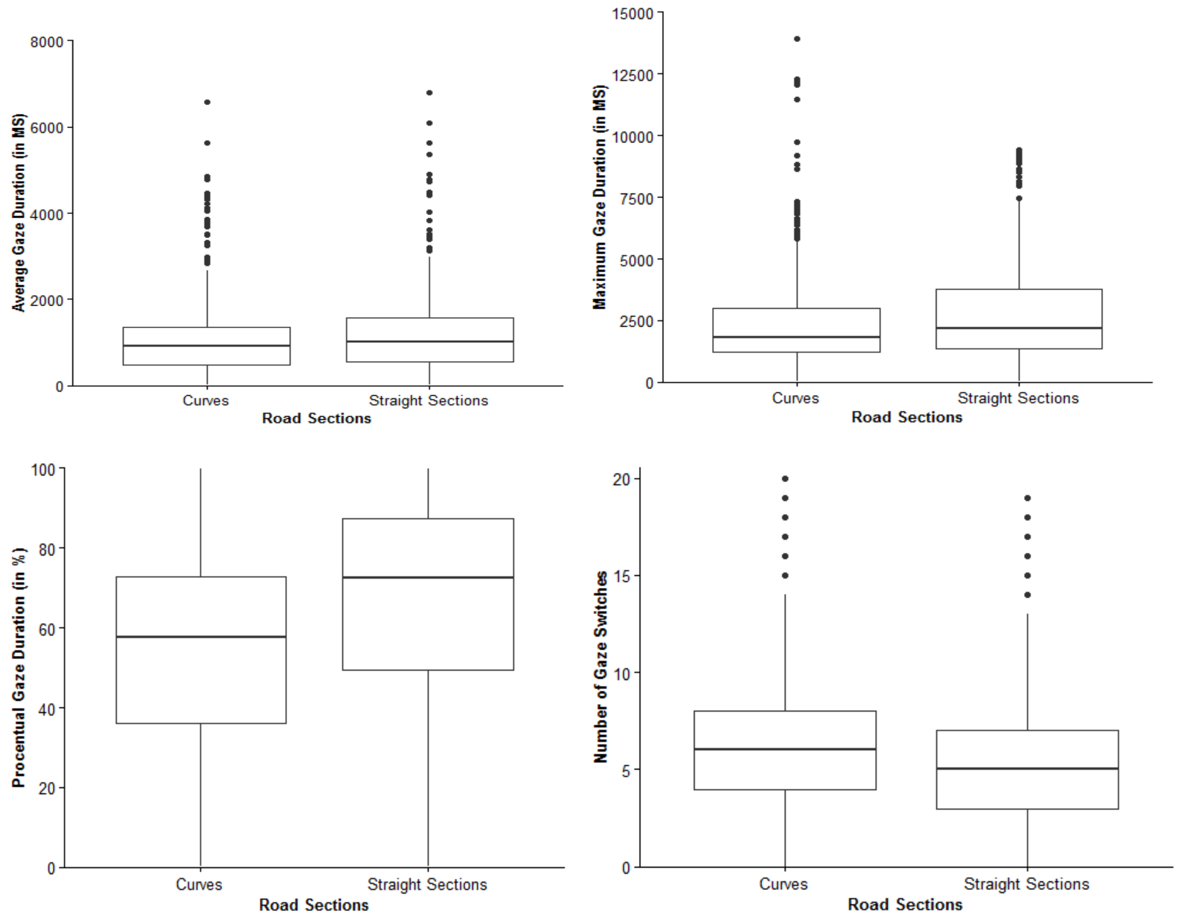






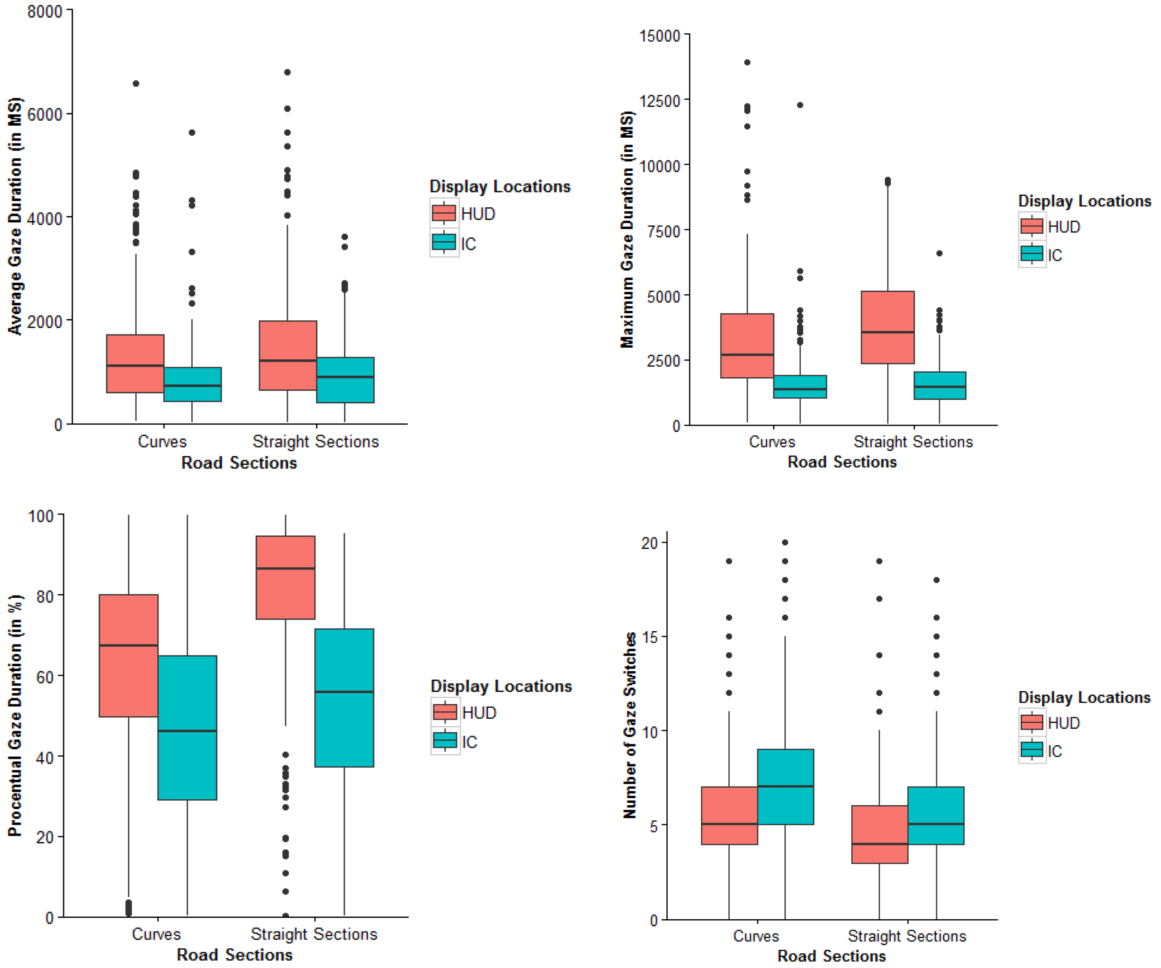

```
#Roadsection comparison
#All Display_Locations combined over the four road sections
Roadsection_Mean<-ggplot(Dataframeclean, aes(Roadsections, Mean_MS_Target))
Roadsection_Mean + geom_boxplot() +
  scale_y_continuous( "Average Gaze Duration (in MS)", limits = c(0,8000), breaks = seq( 0,
8000, by = 2000), expand = c(0,0)) +
  scale_x_discrete( "Road Sections") +
  #scale_fill_discrete (name = "Display Location", breaks = c ("1", "2"), labels = c("HUD",
"IC")) +
  theme_bw () +
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 10),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
```

```
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 10),
        legend.text = element_text (family = "sans", size = 10),
        strip.text.x = element_text (family = "sans", size = 10)
        )

## Warning: Removed 66 rows containing non-finite values (stat_boxplot).
```

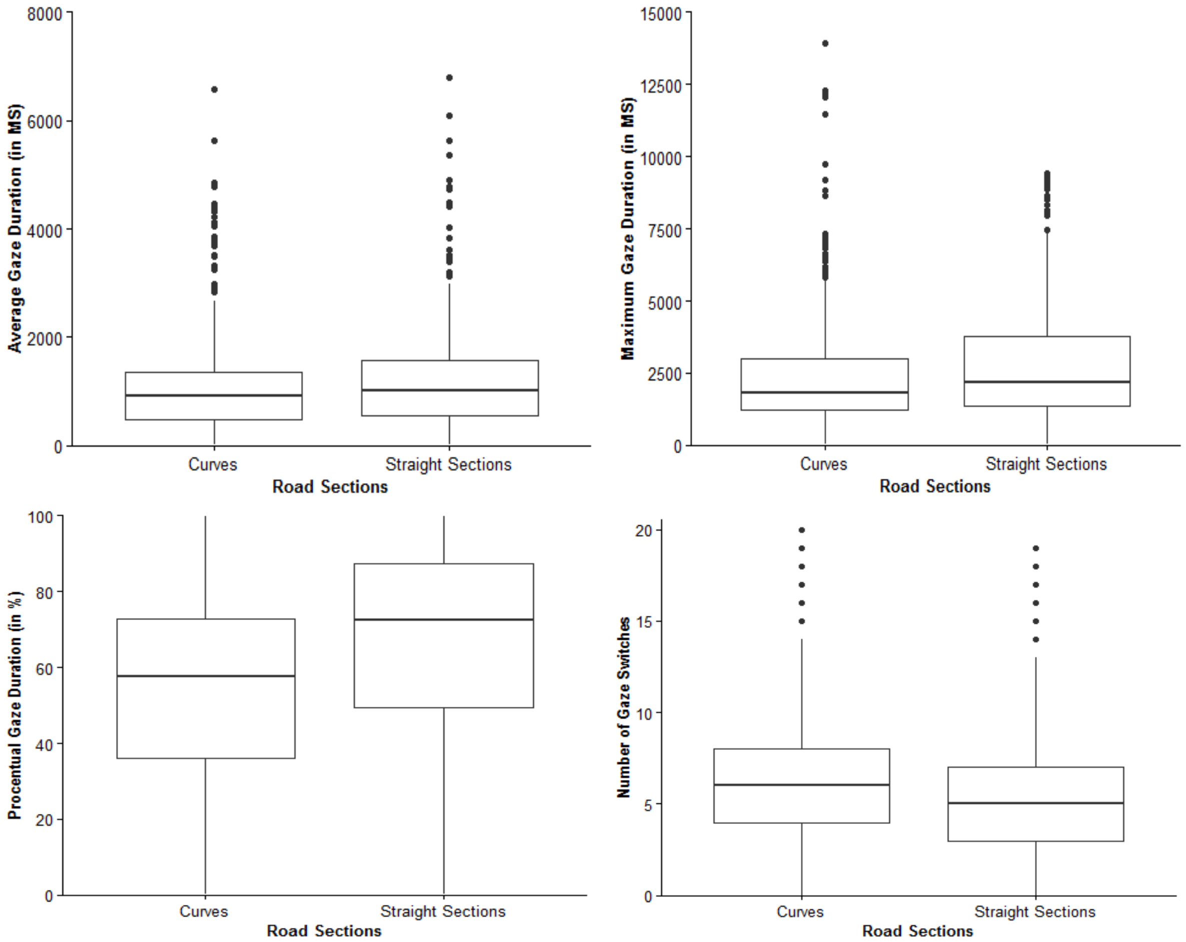



```
#Separate per Display_Locations
Roadsection_Mean<-ggplot(Dataframeclean, aes(Roadsections, Mean_MS_Target, fill = Display
))
Roadsection_Mean + geom_boxplot() +
  scale_y_continuous( "Average Gaze Duration (in MS)", limits = c(0,8000), breaks = seq( 0,
8000, by = 2000), expand = c(0,0)) +
  scale_x_discrete( "Road Sections") +
  scale_fill_discrete (name = "Display Locations", breaks = c ("1", "2"), labels = c("HUD",
"IC")) +
  theme_bw () +
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 10),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 10),
        legend.text = element_text (family = "sans", size = 10),
        strip.text.x = element_text (family = "sans", size = 10)
        )
```

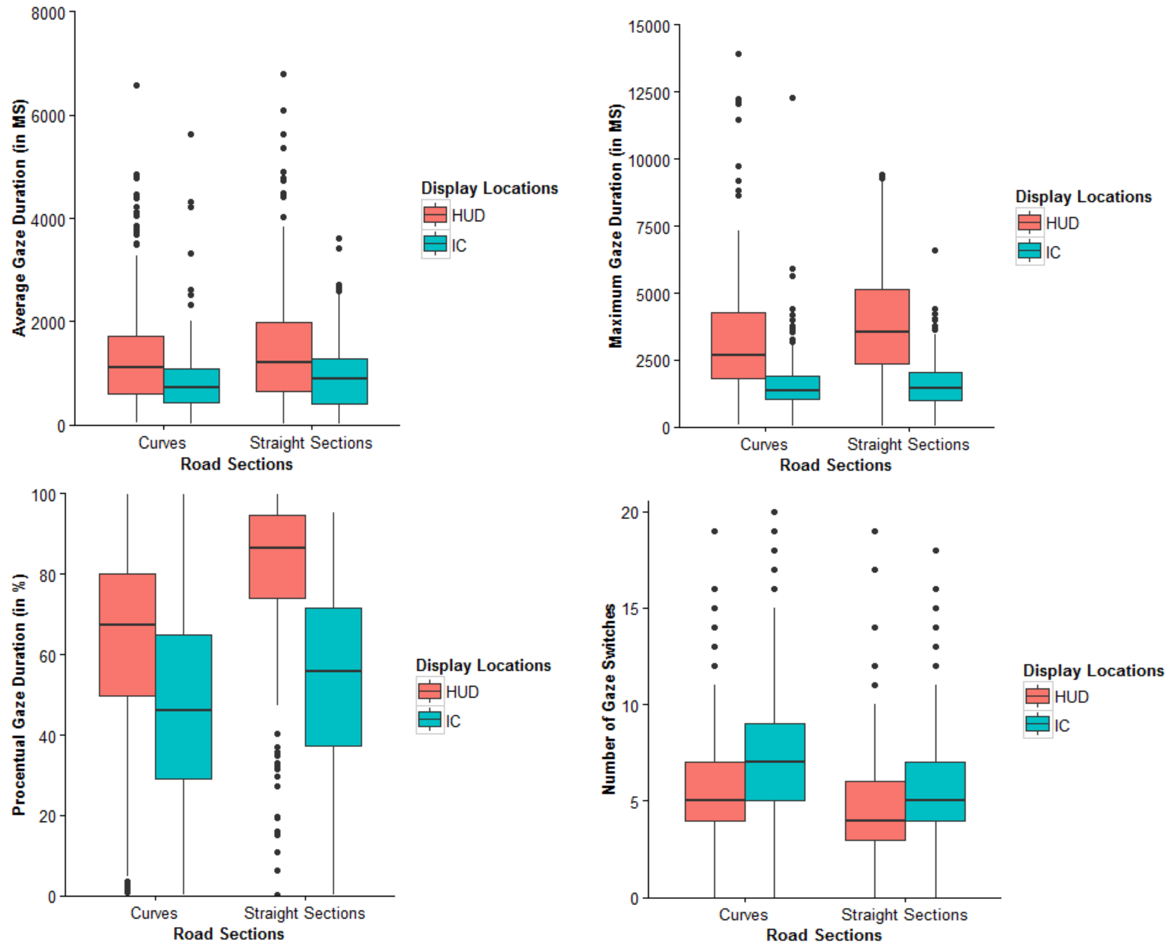
```
## Warning: Removed 66 rows containing non-finite values (stat_boxplot).
```



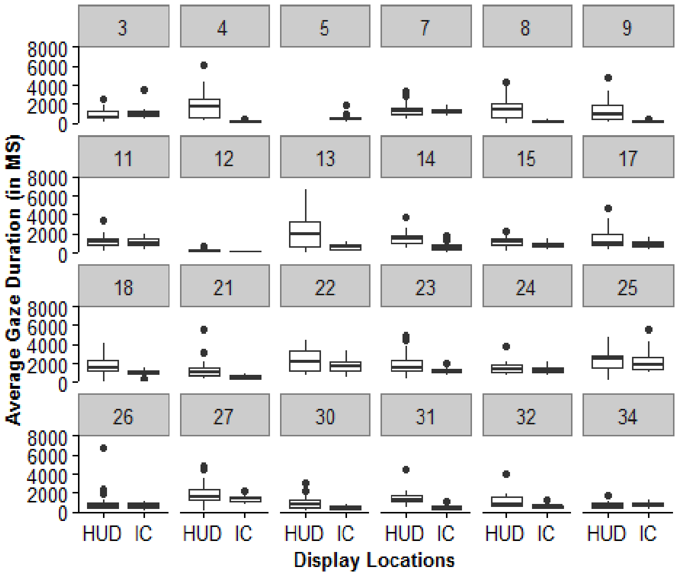

```
#All Display_Locations combined over the curves and straight sections (1 = curve; 2 =
straight section)
Road_Sections_Mean<-ggplot(Dataframeclean, aes(Roadsections, Mean_MS_Target))
Road_Sections_Mean + geom_boxplot() +
   scale_y_continuous( "Average Gaze Duration (in MS)", limits = c(0,8000), breaks = seq(
0, 8000, by = 2000), expand = c(0,0)) +
  scale_x_discrete( "Road Sections") +
  #scale_fill_discrete (name = "Display Locations", breaks = c ("1", "2"), labels =
c("HUD", "IC")) +
  theme_bw () +
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 10),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 10),
        legend.text = element_text (family = "sans", size = 10),
        strip.text.x = element_text (family = "sans", size = 10)
        )

## Warning: Removed 66 rows containing non-finite values (stat_boxplot).
```




```
#Separate per Display_Locations
Road_Sections_Mean<-ggplot(Dataframeclean, aes(Roadsections, Mean_MS_Target, fill = Display
))
Road_Sections_Mean + geom_boxplot() +
     scale_y_continuous( "Average Gaze Duration (in MS)", limits = c(0,8000), breaks = seq(
0, 8000, by = 2000), expand = c(0,0)) +
  scale_x_discrete( "Road Sections") +
  scale_fill_discrete (name = "Display Locations", breaks = c ("1", "2"), labels = c("HUD",
"IC")) +
  theme_bw () +
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 10),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 10),
        legend.text = element_text (family = "sans", size = 10),
        strip.text.x = element_text (family = "sans", size = 10)
        )

## Warning: Removed 66 rows containing non-finite values (stat_boxplot).
```




```
#Plots on the individual level
#Display_Locations comparison
Disp_Mean_pp<-ggplot(Dataframeclean, aes(Display_Locations, Mean_MS_Target))
Disp_Mean_pp + geom_boxplot() + facet_wrap( ~ VP, ncol = 6)+
   scale_y_continuous( "Average Gaze Duration (in MS)", limits = c(0,8000), breaks = seq(
0, 8000, by = 2000), expand = c(0,0)) +
  scale_x_discrete( "Display Locations") +
  #scale_fill_discrete (name = "Display Location", breaks = c ("1", "2"), labels = c("HUD",
"IC")) +
  theme_bw () +
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 10),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 10),
        legend.text = element_text (family = "sans", size = 10),
        strip.text.x = element_text (family = "sans", size = 10)
        )

## Warning: Removed 66 rows containing non-finite values (stat_boxplot).
```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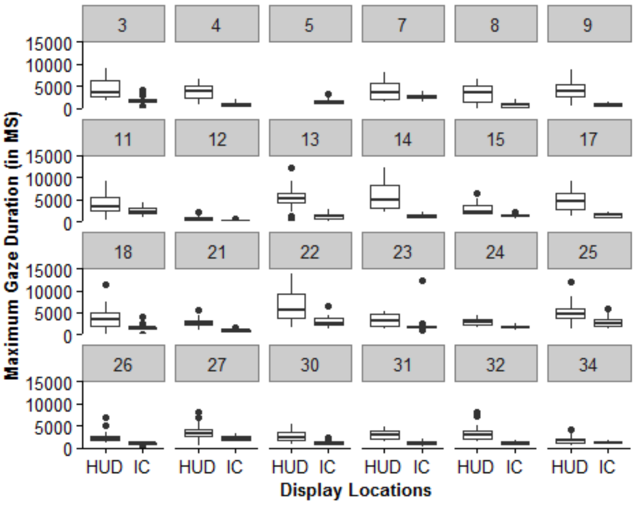
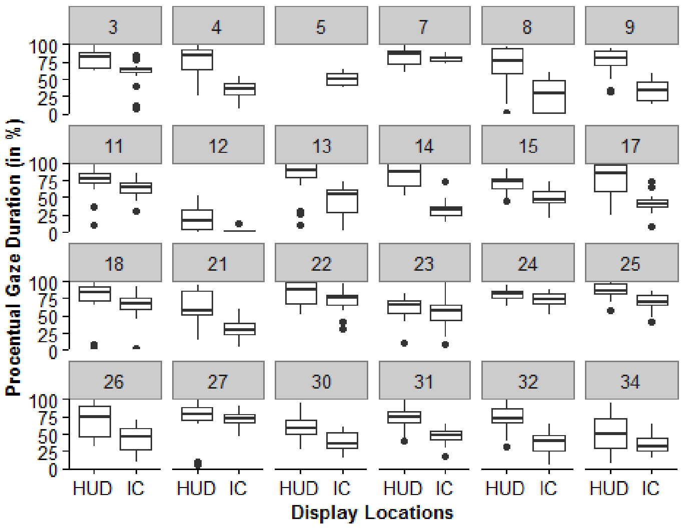
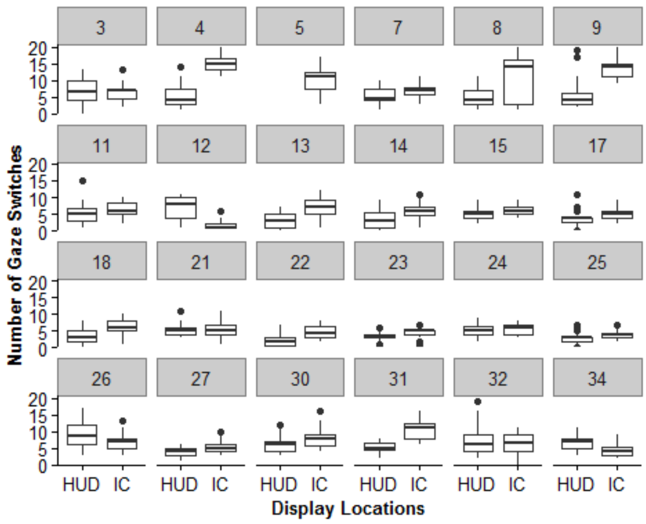
8000
6000
4000
2000
0
Average Gaze Duration (in MS)
HUD IC
Display Locations

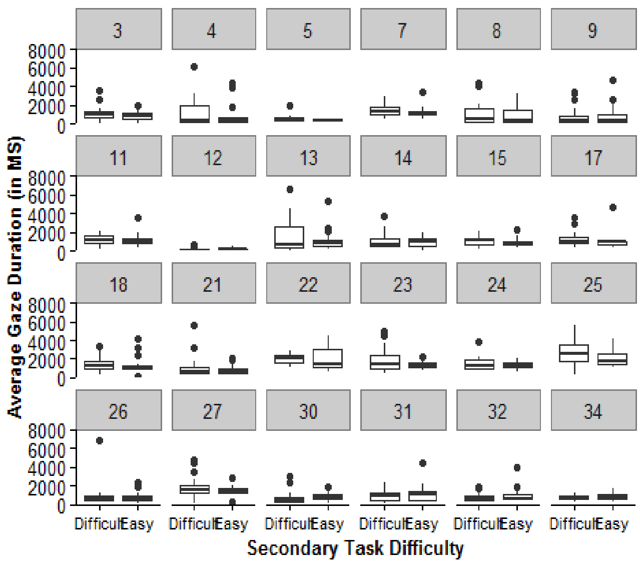

3
4
5
7
8
9
11
12
13
14
15
17
18
21
22
23
24
25
26
27
30
31
32
34
15000
10000
5000
0
Maximum Gaze Duration (in MS)
HUD IC
Display Locations

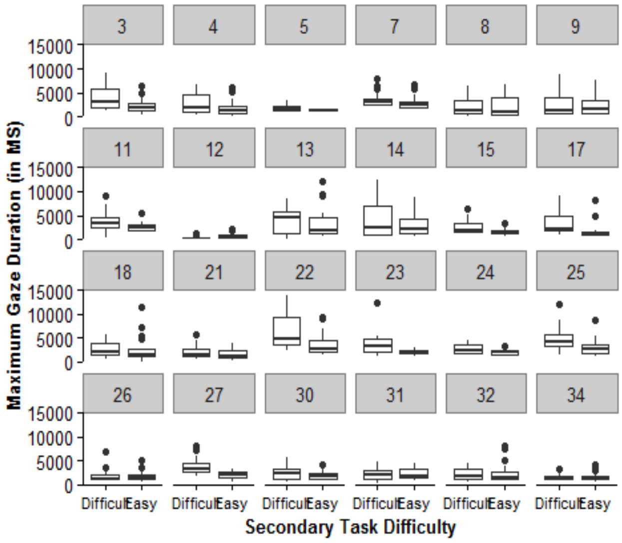

3
4
5
7
8
9
11
12
13
14
15
17
18
21
22
23
24
25
26
27
30
31
32
34
100
75
50
25
0
Procentual Gaze Duration (in %)
HUD IC
Display Locations

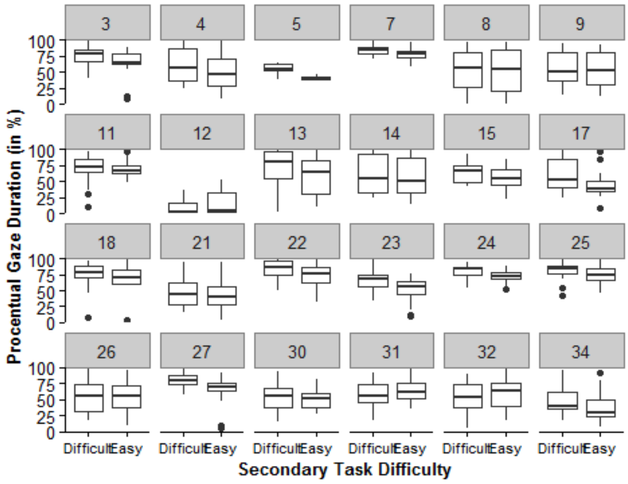


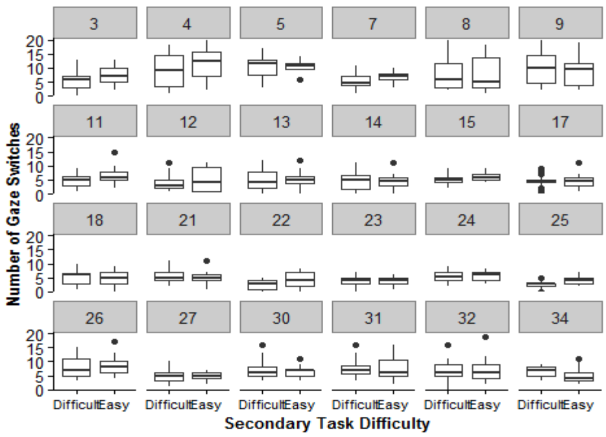

```
#Tasklevel comparison
#All Display_Locations combined
SecTaskDiff_Mean_pp<-ggplot(Dataframeclean, aes(Secondary_Task_Difficulty, Mean_MS_Target))
SecTaskDiff_Mean_pp + geom_boxplot() + facet_wrap( ~ VP, ncol = 6) +
   scale_y_continuous( "Average Gaze Duration (in MS)", limits = c(0,8000), breaks = seq(
0, 8000, by = 2000), expand = c(0,0)) +
  scale_x_discrete( "Secondary Task Difficulty") +
  #scale_fill_discrete (name = "Display Location", breaks = c ("1", "2"), labels = c("HUD",
"IC")) +
  theme_bw () +
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 8),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 10),
        legend.text = element_text (family = "sans", size = 10),
        strip.text.x = element_text (family = "sans", size = 10)
        )

## Warning: Removed 66 rows containing non-finite values (stat_boxplot).
```





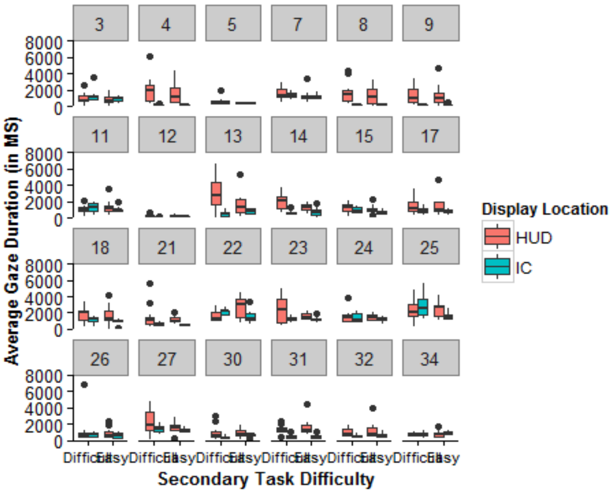


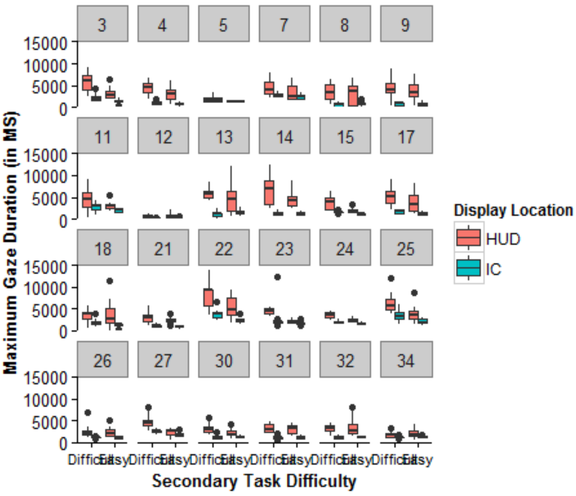


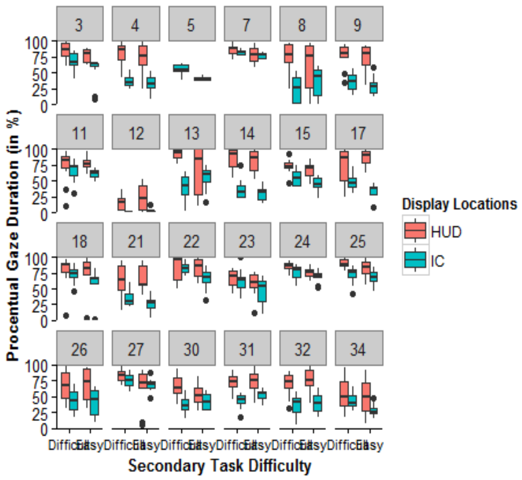

```
#Separate per Display_Locations
SecTaskDiff_Mean_pp<-ggplot(Dataframeclean, aes(Secondary_Task_Difficulty, Mean_MS_Target,
fill = Display ))
SecTaskDiff_Mean_pp + geom_boxplot() +  facet_wrap( ~ VP, ncol = 6)+
   scale_y_continuous( "Average Gaze Duration (in MS)", limits = c(0,8000), breaks = seq(
0, 8000, by = 2000), expand = c(0,0)) +
  scale_x_discrete( "Secondary Task Difficulty") +
  scale_fill_discrete (name = "Display Location", breaks = c ("1", "2"), labels = c("HUD",
"IC")) +
  theme_bw () +
```

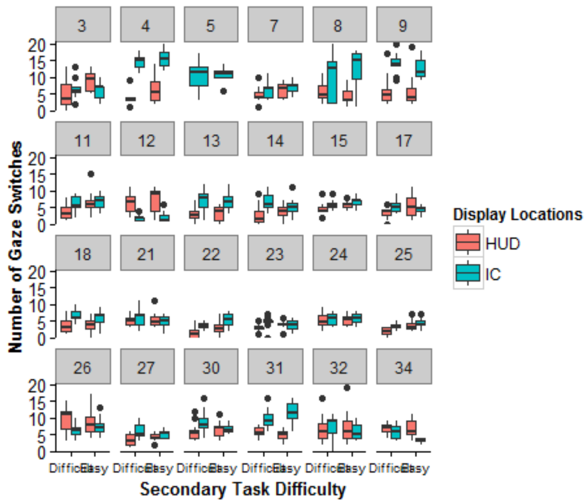
```
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 8),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 9),
        legend.text = element_text (family = "sans", size = 9),
        strip.text.x = element_text (family = "sans", size = 10)
        )

## Warning: Removed 66 rows containing non-finite values (stat_boxplot).
```



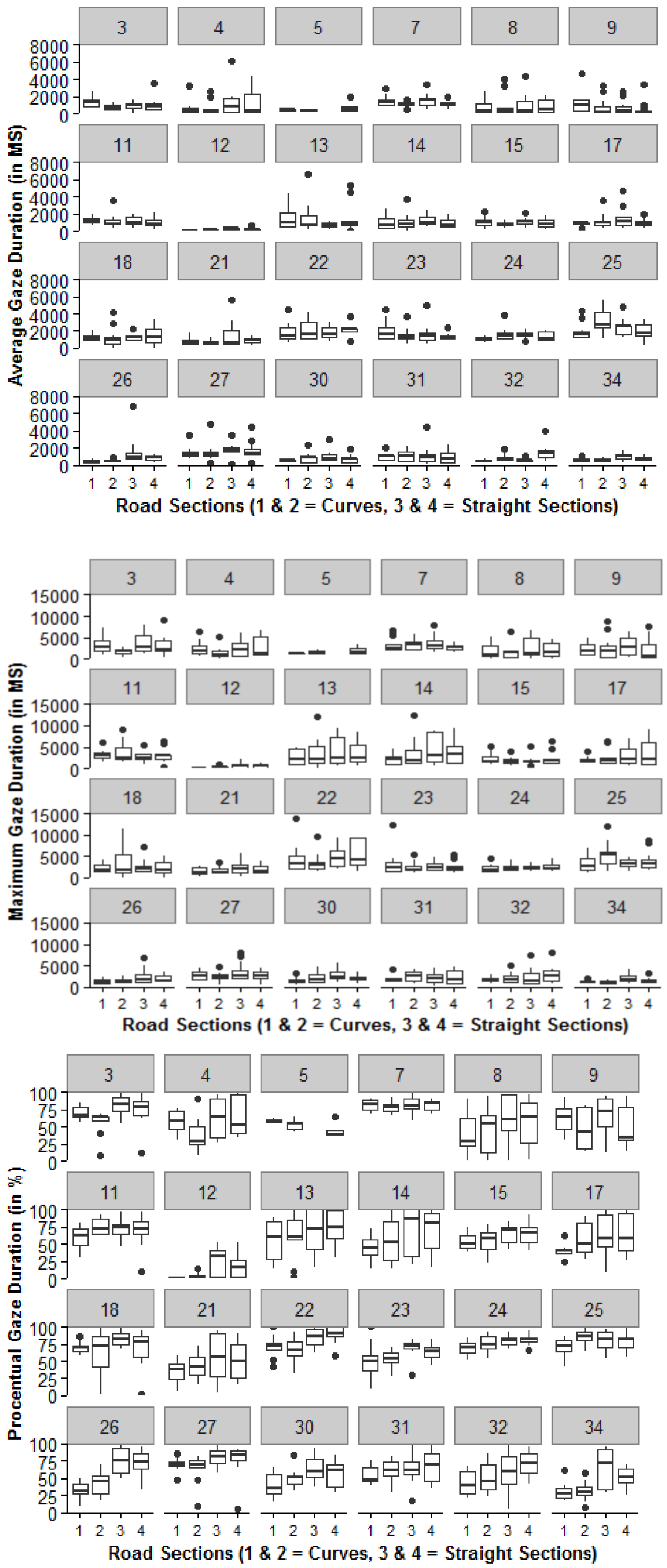




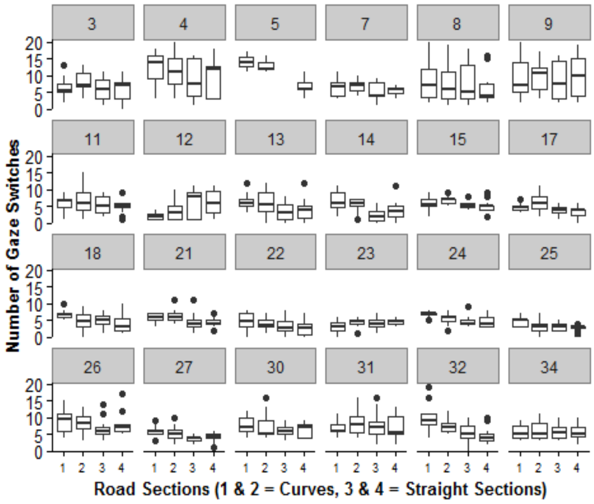



```
#Roadsection comparison
#All Display_Locations combined over the four road sections
Roadsection_Mean_pp<-ggplot(Dataframeclean, aes(Roadsection, Mean_MS_Target))
Roadsection_Mean_pp + geom_boxplot() +  facet_wrap( ~ VP, ncol = 6)+
 scale_y_continuous( "Average Gaze Duration (in MS)", limits = c(0,8000), breaks = seq( 0,
8000, by = 2000), expand = c(0,0)) +
  scale_x_discrete( "Road Sections (1 & 2 = Curves, 3 & 4 = Straight Sections)") +
  #scale_fill_discrete (name = "Display Location", breaks = c ("1", "2"), labels = c("HUD",
"IC")) +
  theme_bw () +
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 8),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 9),
        legend.text = element_text (family = "sans", size = 9),
        strip.text.x = element_text (family = "sans", size = 10)
        )

## Warning: Removed 66 rows containing non-finite values (stat_boxplot).
```

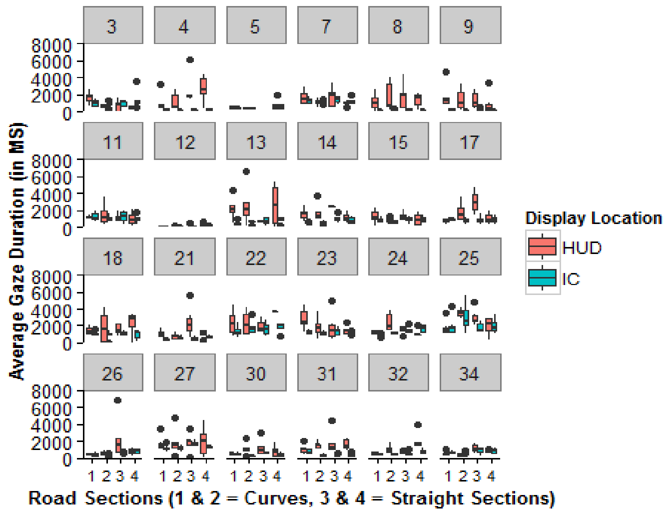


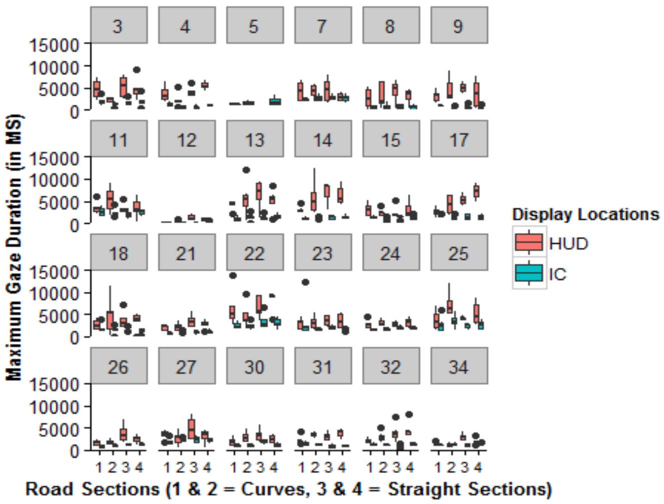
Average Gaze Duration (in MS)
Road Sections (1 & 2 = Curves, 3 & 4 = Straight Sections)
Maximum Gaze Duration (in MS)
Road Sections (1 & 2 = Curves, 3 & 4 = Straight Sections)
Procentual Gaze Duration (in %)
Road Sections (1 & 2 = Curves, 3 & 4 = Straight Sections)

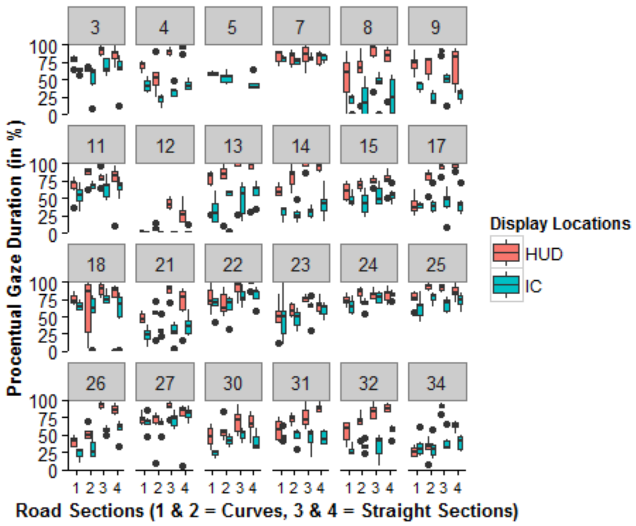


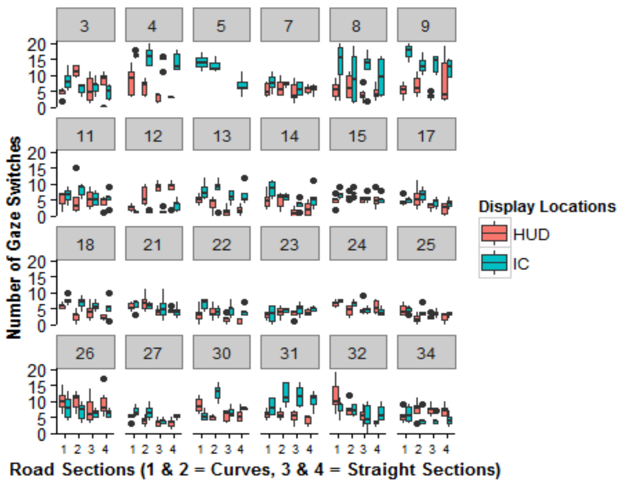

```
#Separate per Display_Locations
Roadsection_Mean_pp <-ggplot(Dataframeclean, aes(Roadsection, Mean_MS_Target, fill =
Display ))
Roadsection_Mean_pp + geom_boxplot() +  facet_wrap( ~ VP, ncol = 6)+
 scale_y_continuous( "Average Gaze Duration (in MS)", limits = c(0,8000), breaks = seq( 0,
8000, by = 2000), expand = c(0,0)) +
  scale_x_discrete( "Road Sections (1 & 2 = Curves, 3 & 4 = Straight Sections)") +
  scale_fill_discrete (name = "Display Location", breaks = c ("1", "2"), labels = c("HUD",
"IC")) +
  theme_bw () +
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 8),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 9),
        legend.text = element_text (family = "sans", size = 9),
        strip.text.x = element_text (family = "sans", size = 10)
        )

## Warning: Removed 66 rows containing non-finite values (stat_boxplot).
```





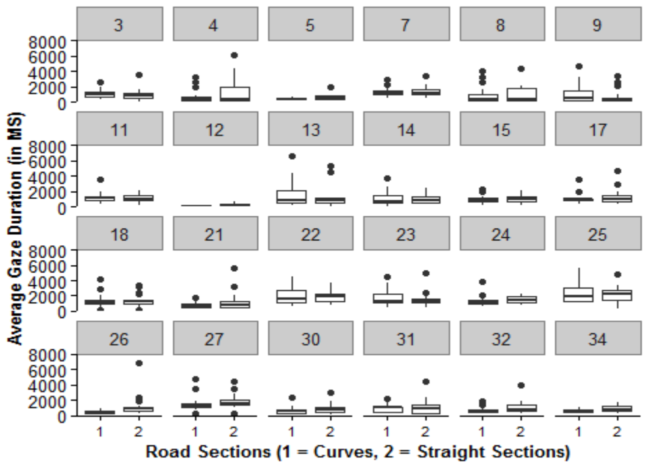


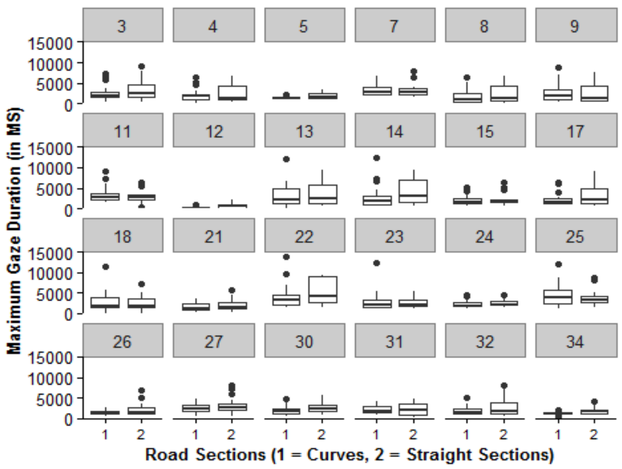


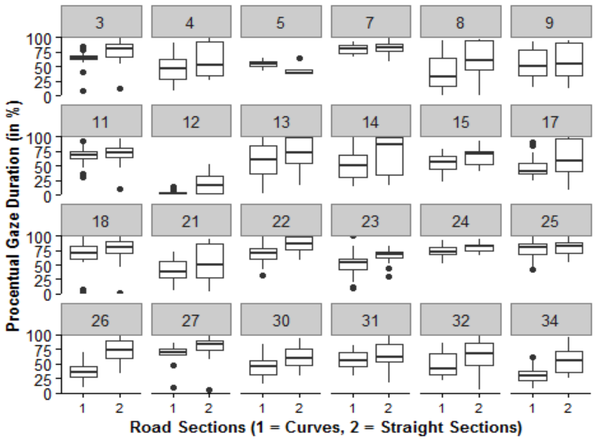

```
#All Display_Locations combined over the curves and straight sections (1 = curve; 2 =
straight sectioN)
Road_Sections_Mean_pp<-ggplot(Dataframeclean, aes(RoadsectionRec, Mean_MS_Target))
Road_Sections_Mean_pp + geom_boxplot() +  facet_wrap( ~ VP, ncol = 6)+
 scale_y_continuous( "Average Gaze Duration (in MS)", limits = c(0,8000), breaks = seq( 0,
8000, by = 2000), expand = c(0,0)) +
  scale_x_discrete( "Road Sections (1 = Curves, 2 = Straight Sections)") +
  #scale_fill_discrete (name = "Display Location", breaks = c ("1", "2"), labels = c("HUD",
```

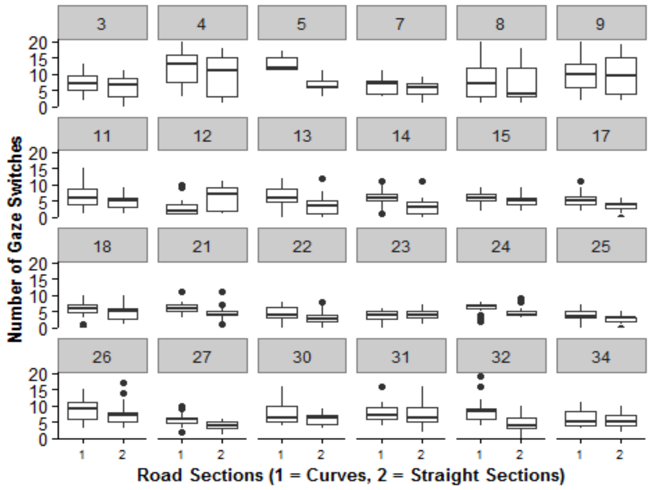
```
"IC")) +
  theme_bw () +
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 8),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 9),
        legend.text = element_text (family = "sans", size = 9),
        strip.text.x = element_text (family = "sans", size = 10)
        )

## Warning: Removed 66 rows containing non-finite values (stat_boxplot).
```



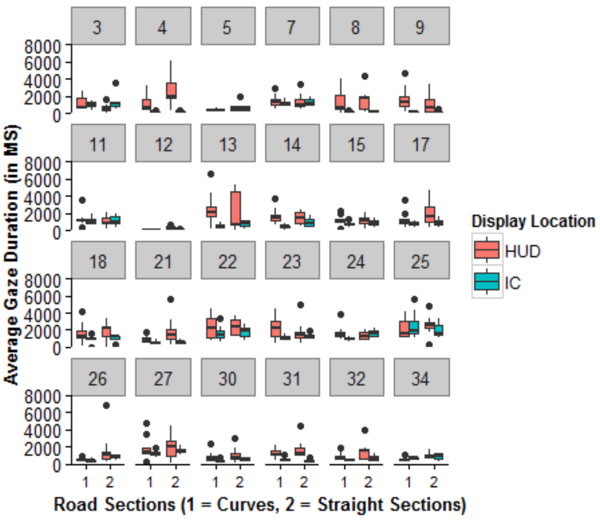


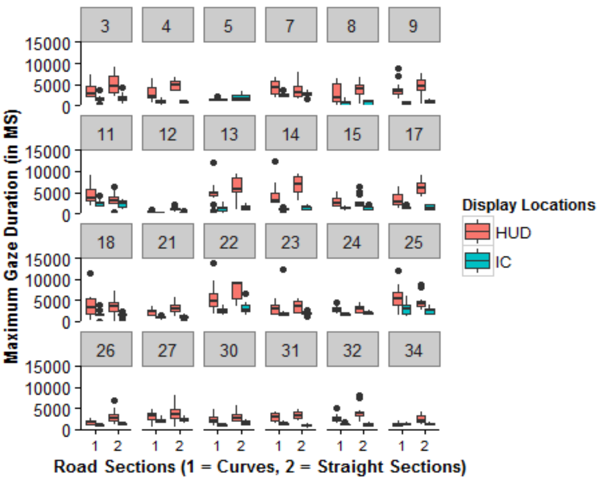


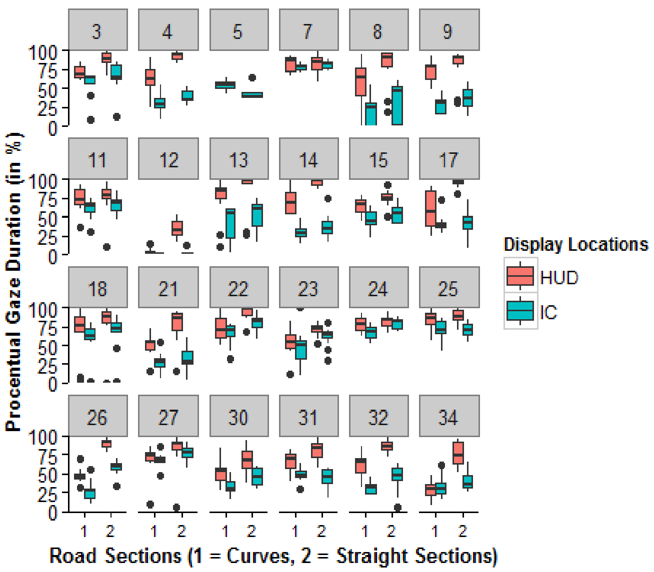


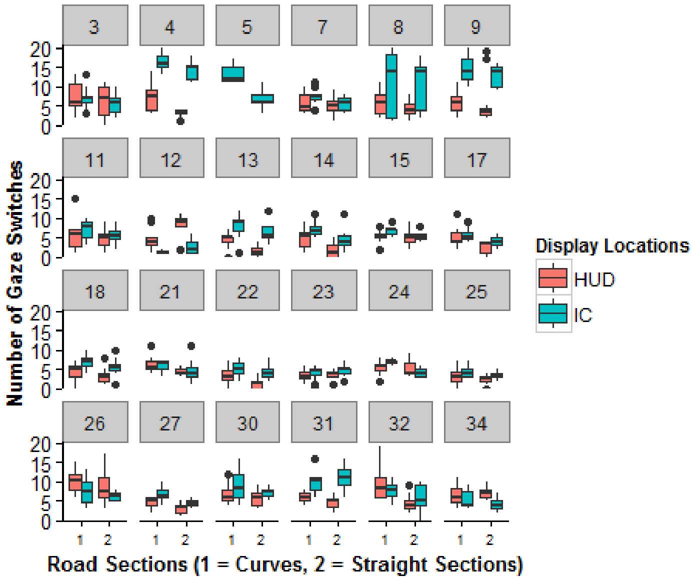

```
#Separate per Display_Locations
Road_Sections_Mean_pp<-ggplot(Dataframeclean, aes(RoadsectionRec, Mean_MS_Target, fill =
Display ))
Road_Sections_Mean_pp + geom_boxplot() + facet_wrap( ~ VP, ncol = 6)+
 scale_y_continuous( "Average Gaze Duration (in MS)", limits = c(0,8000), breaks = seq( 0,
8000, by = 2000), expand = c(0,0)) +
  scale_x_discrete( "Road Sections (1 = Curves, 2 = Straight Sections)") +
  scale_fill_discrete (name = "Display Location", breaks = c ("1", "2"), labels = c("HUD",
"IC")) +
  theme_bw () +
  theme(axis.title.x = element_text (family = "sans", face = "bold", size =10),
        axis.title.y = element_text (family ="sans", face = "bold", size = 10, angle = 90),
        axis.text.x = element_text (family = "sans", size = 8),
        axis.text.y = element_text (family = "sans", size = 10),
        axis.line.x = element_line( colour = "black"),
        axis.line.y = element_line( colour = "black"),
        panel.grid.major = element_line (colour = "white"),
        panel.grid.minor = element_line (colour = "white"),
        panel.border = element_rect ( colour = "white"),
        legend.title = element_text (family = "sans", face = "bold", size = 9),
        legend.text = element_text (family = "sans", size = 9),
        strip.text.x = element_text (family = "sans", size = 10)
        )

## Warning: Removed 66 rows containing non-finite values (stat_boxplot).
```


Average Gaze Duration (in MS)
Road Sections (1 = Curves, 2 = Straight Sections)
Display Location
HUD
IC


Maximum Gaze Duration (in MS)
Road Sections (1 = Curves, 2 = Straight Sections)
Display Locations
HUD
IC


Procentual Gaze Duration (in %)
Road Sections (1 = Curves, 2 = Straight Sections)
Display Locations
HUD
IC


3
4
5
7
8
9
11
12
13
14
15
17
18
21
22
23
24
25
26
27
30
31
32
34
20
15
10
5
0
Number of Gaze Switches
Display Locations
HUD
IC
1
2
Road Sections (1 = Curves, 2 = Straight Sections)

Appendix E

Table 10

Descriptive Statistics for the Average and Maximum Gaze Duration

	Average Gaze Duration (in MS)			Maximum Gaze Duration (in MS)		
	N	*M*	*SD*	*N*	*M*	*SD*
Total	986	1154.11	956.4	1039	2619.57	2024.72
Display						
HUD	477	1434.84	1138.31	525	3632.05	2246.01
IC	509	891.02	645.04	514	1585.43	1010.69
Secondary Task Difficulty						
Easy	496	1093.25	828.69	514	2256.30	1746.07
Difficult	490	1215.70	1067.60	525	2975.23	2209.03
Roadsection						
Curves	501	1103.06	930.35	516	2432.13	1965.47
Straights	485	1206.84	980.74	523	2804.51	2066.79

Table 11

Descriptive Statistics for the Procentual Gaze Duration and the Number of Gaze Switches

	Procentual Gaze Duration (in %)			Number of Gaze Switches		
	N	*M*	*SD*	*N*	*M*	*SD*
Total	1039	60.73	25.74	1039	5.95	3.61
Display						
HUD	525	71.54	23.67	525	5.10	3.12
IC	514	49.68	22.94	514	6.82	3.87
Secondary Task Difficulty						
Easy	514	58.06	25.72	514	6.07	3.52
Difficult	525	63.33	25.51	525	5.84	3.71
Roadsection						
Curves	516	54.24	24.44	516	6.60	3.63
Straights	523	67.12	25.41	523	5.31	3.48

Appendix F

The R Scripts and the relevant results of the LME models.

```
D <-
  read.spss("Datensatz_SchmidtMAVW_130616_v2.sav",
            to.data.frame = TRUE) %>%
  as_data_frame() %>%
  select(VP:Roadsection, Mean_MS_Target:PGD_MS_Target) %>%
  filter(!is.na(Max_MS_Target)) %>%
  mutate(Obs = row_number())

## Warning in read.spss("Datensatz_SchmidtMAVW_130616_v2.sav", to.data.frame
## = TRUE): Datensatz_SchmidtMAVW_130616_v2.sav: Unrecognized record type 7,
## subtype 18 encountered in system file

#D$RoadsectionRec <- relevel(D$RoadsectionRec, "Straight Sections")
D$Display <- relevel(D$Display, "IC" )

#### Maximum Gaze Duration
 options (digits = 4)
 MaxDur_stan <-stan_lmer(Max_MS_Target ~ Display * RoadsectionRec * SecTaskDif +
                ((Display * RoadsectionRec * SecTaskDif) | VP),
               data = D)

options (digits = 4)
 print(MaxDur_stan, digits = 4)

## stan_lmer(formula = Max_MS_Target ~ Display * RoadsectionRec *
##     SecTaskDif + ((Display * RoadsectionRec * SecTaskDif) | VP),
##     data = D)
##
## Estimates:
##                                                                Median
## (Intercept)                                                    1355.6732
## DisplayHUD                                                     1278.9098
## RoadsectionRecStraight Sections                                  40.5027
## SecTaskDifDifficult                                             356.8628
## DisplayHUD:RoadsectionRecStraight Sections                      900.5185
## DisplayHUD:SecTaskDifDifficult                                  891.2059
## RoadsectionRecStraight Sections:SecTaskDifDifficult              17.3308
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult -344.9787
## sigma                                                          1315.3426
##                                                                MAD_SD
## (Intercept)                                                     153.6861
## DisplayHUD                                                      225.4957
## RoadsectionRecStraight Sections                                 170.4135
## SecTaskDifDifficult                                             199.3818
## DisplayHUD:RoadsectionRecStraight Sections                      270.0326
## DisplayHUD:SecTaskDifDifficult                                  251.0639
## RoadsectionRecStraight Sections:SecTaskDifDifficult             235.7888
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult  339.6963
## sigma                                                            29.8540
##
## Error terms:
##  Groups   Name
##  VP       (Intercept)
##           DisplayHUD
##           RoadsectionRecStraight Sections
##           SecTaskDifDifficult
##           DisplayHUD:RoadsectionRecStraight Sections
##           DisplayHUD:SecTaskDifDifficult
##           RoadsectionRecStraight Sections:SecTaskDifDifficult
##           DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult
##  Residual
##  Std.Dev. Corr
```

```
##   477.78
##   722.45   0.134
##   168.74  -0.207  0.127
##   436.15   0.524  0.157 -0.046
##   551.24  -0.382  0.246  0.162 -0.228
##   356.81   0.388  0.333  0.109  0.358  0.122
##   116.95   0.141 -0.013 -0.131 -0.027 -0.060  0.105
##   154.36   0.039 -0.275 -0.029  0.051 -0.255 -0.125 -0.041
##  1315.34
## Num. levels: VP 24
##
## Sample avg. posterior predictive
## distribution of y (X = xbar):
##          Median    MAD_SD
## mean_PPD 2618.8142   55.9649
```

```
summary (MaxDur_stan, digits = 4)
```

```
## stan_lmer(formula = Max_MS_Target ~ Display * RoadsectionRec *
##     SecTaskDif + ((Display * RoadsectionRec * SecTaskDif) | VP),
##     data = D)
##
## Family: gaussian (identity)
## Algorithm: sampling
## Posterior sample size: 4000
## Observations: 1039
## Groups: VP 24
##
## Estimates:
##                                                                       mean
## (Intercept)                                                         1352.4042
## DisplayHUD                                                          1275.4267
## RoadsectionRecStraight Sections                                       39.6393
## SecTaskDifDifficult                                                  360.2525
## DisplayHUD:RoadsectionRecStraight Sections                           899.4621
## DisplayHUD:SecTaskDifDifficult                                       891.7980
## RoadsectionRecStraight Sections:SecTaskDifDifficult                   16.1303
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult      -339.3550
23.9346
## sigma                                                               1315.9950
## mean_PPD                                                            2620.0068
## log-posterior                                                      -8133.2762
##                                                                       sd
## (Intercept)                                                          153.1348
## DisplayHUD                                                           226.4146
## RoadsectionRecStraight Sections                                      173.3864
## SecTaskDifDifficult                                                  197.3364
## DisplayHUD:RoadsectionRecStraight Sections                           272.1447
## DisplayHUD:SecTaskDifDifficult                                       253.7404
## RoadsectionRecStraight Sections:SecTaskDifDifficult                  239.7549
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult       337.9556
## sigma                                                                 30.2811
## mean_PPD                                                              56.6627
## log-posterior                                                         13.4021
##                                                                       2.5%
## (Intercept)                                                         1043.0614
## DisplayHUD                                                           830.3769
## RoadsectionRecStraight Sections                                     -295.9850
## SecTaskDifDifficult                                                  -24.4188
## DisplayHUD:RoadsectionRecStraight Sections                           358.1181
## DisplayHUD:SecTaskDifDifficult                                       395.1504
## RoadsectionRecStraight Sections:SecTaskDifDifficult                 -448.9413
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult     -1019.8007
## sigma                                                               1256.7360
## mean_PPD                                                            2510.9951
## log-posterior                                                      -8160.4901
```

```
##                                                                       97.5%
## (Intercept)                                                          1640.6107
## DisplayHUD                                                           1706.5775
## RoadsectionRecStraight Sections                                       381.3702
## SecTaskDifDifficult                                                   746.8932
## DisplayHUD:RoadsectionRecStraight Sections                           1422.9521
## DisplayHUD:SecTaskDifDifficult                                       1394.8217
## RoadsectionRecStraight Sections:SecTaskDifDifficult                   496.8723
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult        326.0245
## sigma                                                                1376.0192
## mean_PPD                                                             2733.6291
## log-posterior                                                       -8108.8278
```

```
 #### Gaze Percentage
 options(digits = 4)
 PGD_stan <-stan_lmer(PGD_MS_Target ~ Display * RoadsectionRec * SecTaskDif +
             ((Display * RoadsectionRec * SecTaskDif) | VP),
           data = D)

options (digits = 4)
 print(PGD_stan, digits = 4)
```

```
## stan_lmer(formula = PGD_MS_Target ~ Display * RoadsectionRec *
##     SecTaskDif + ((Display * RoadsectionRec * SecTaskDif) | VP),
##     data = D)
##
## Estimates:
##                                                                 Median
## (Intercept)                                                     41.6699
## DisplayHUD                                                      17.3922
## RoadsectionRecStraight Sections                                  8.2168
## SecTaskDifDifficult                                              6.1458
## DisplayHUD:RoadsectionRecStraight Sections                      11.6927
## DisplayHUD:SecTaskDifDifficult                                   0.1538
## RoadsectionRecStraight Sections:SecTaskDifDifficult             -0.2003
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult -2.3935
## sigma                                                           15.2535
##                                                                 MAD_SD
## (Intercept)                                                      3.5142
## DisplayHUD                                                       2.9465
## RoadsectionRecStraight Sections                                  2.1624
## SecTaskDifDifficult                                              2.0727
## DisplayHUD:RoadsectionRecStraight Sections                       3.3136
## DisplayHUD:SecTaskDifDifficult                                   2.8809
## RoadsectionRecStraight Sections:SecTaskDifDifficult              2.8109
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult   3.8457
## sigma                                                            0.3501
##
## Error terms:
##  Groups   Name
##  VP       (Intercept)
##           DisplayHUD
##           RoadsectionRecStraight Sections
##           SecTaskDifDifficult
##           DisplayHUD:RoadsectionRecStraight Sections
##           DisplayHUD:SecTaskDifDifficult
##           RoadsectionRecStraight Sections:SecTaskDifDifficult
##           DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult
##  Residual
##  Std.Dev. Corr
##  15.6738
##  10.3072  -0.319
##   3.9163  -0.204 -0.014
##   3.4446   0.277 -0.282 -0.002
##   8.0924  -0.667  0.146  0.111 -0.110
##   4.7272   0.087  0.053  0.017 -0.427 -0.272
```

```
##   2.1506   0.385 -0.058 -0.129  0.135 -0.149 -0.118
##   1.8682  -0.071  0.175  0.176  0.035 -0.048 -0.004 -0.104
##  15.2535
## Num. levels: VP 24
##
## Sample avg. posterior predictive
## distribution of y (X = xbar):
##          Median  MAD_SD
## mean_PPD 60.7049  0.6641
```

```
summary (PGD_stan, digits = 4)
```

```
## stan_lmer(formula = PGD_MS_Target ~ Display * RoadsectionRec *
##     SecTaskDif + ((Display * RoadsectionRec * SecTaskDif) | VP),
##     data = D)
##
## Family: gaussian (identity)
## Algorithm: sampling
## Posterior sample size: 4000
## Observations: 1039
## Groups: VP 24
##
## Estimates:
##                                                                      mean
## (Intercept)                                                           41.6166
## DisplayHUD                                                            17.3852
## RoadsectionRecStraight Sections                                        8.2307
## SecTaskDifDifficult                                                    6.0957
## DisplayHUD:RoadsectionRecStraight Sections                            11.6718
## DisplayHUD:SecTaskDifDifficult                                         0.1897
## RoadsectionRecStraight Sections:SecTaskDifDifficult                   -0.1030
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult        -2.3718
## sigma                                                                 15.2597
## mean_PPD                                                              60.7130
## log-posterior                                                      -3500.8803
##                                                                      sd
## (Intercept)                                                            3.4603
## DisplayHUD                                                             3.0014
## RoadsectionRecStraight Sections                                        2.1501
## SecTaskDifDifficult                                                    2.1122
## DisplayHUD:RoadsectionRecStraight Sections                             3.3418
## DisplayHUD:SecTaskDifDifficult                                         3.0267
## RoadsectionRecStraight Sections:SecTaskDifDifficult                    2.8390
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult         3.9294
## sigma                                                                  0.3553
## mean_PPD                                                               0.6732
## log-posterior                                                         14.6498
##                                                                      2.5%
## (Intercept)                                                           34.7732
## DisplayHUD                                                            11.3798
## RoadsectionRecStraight Sections                                        4.0012
## SecTaskDifDifficult                                                    1.8957
## DisplayHUD:RoadsectionRecStraight Sections                             5.1053
## DisplayHUD:SecTaskDifDifficult                                        -5.7335
## RoadsectionRecStraight Sections:SecTaskDifDifficult                   -5.5914
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult       -10.2340
## sigma                                                                 14.5900
## mean_PPD                                                              59.4090
## log-posterior                                                      -3530.5980
##                                                                      97.5%
## (Intercept)                                                           48.2392
## DisplayHUD                                                            23.3852
## RoadsectionRecStraight Sections                                       12.4668
## SecTaskDifDifficult                                                   10.0981
## DisplayHUD:RoadsectionRecStraight Sections                            18.2316
## DisplayHUD:SecTaskDifDifficult                                         6.1097
```

```
## RoadsectionRecStraight Sections:SecTaskDifDifficult                        5.5038
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult             5.2507
## sigma                                                                     15.9847
## mean_PPD                                                                  62.0241
## log-posterior                                                          -3472.8396
 #### Mean Gaze Duration
 options (digits = 4)
 MeanDur_stan <-stan_lmer(Mean_MS_Target ~ Display * RoadsectionRec * SecTaskDif +
                  ((Display * RoadsectionRec * SecTaskDif) | VP),
                data = D1)

options (digits = 4)
 print(MeanDur_stan, digits = 4)

## stan_lmer(formula = Mean_MS_Target ~ Display * RoadsectionRec *
##     SecTaskDif + ((Display * RoadsectionRec * SecTaskDif) | VP),
##     data = D1)
##
## Estimates:
##                                                                  Median
## (Intercept)                                                       720.5684
## DisplayHUD                                                        521.8574
## RoadsectionRecStraight Sections                                   133.9585
## SecTaskDifDifficult                                               138.9459
## DisplayHUD:RoadsectionRecStraight Sections                        135.9828
## DisplayHUD:SecTaskDifDifficult                                    143.0234
## RoadsectionRecStraight Sections:SecTaskDifDifficult               -12.2169
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult -188.3705
## sigma                                                             762.7220
##                                                                  MAD_SD
## (Intercept)                                                       112.6347
## DisplayHUD                                                        112.9704
## RoadsectionRecStraight Sections                                   101.3712
## SecTaskDifDifficult                                               102.6632
## DisplayHUD:RoadsectionRecStraight Sections                        162.2540
## DisplayHUD:SecTaskDifDifficult                                    156.1281
## RoadsectionRecStraight Sections:SecTaskDifDifficult               142.9073
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult  207.7629
## sigma                                                              18.4178
##
## Error terms:
##  Groups   Name
##  VP       (Intercept)
##           DisplayHUD
##           RoadsectionRecStraight Sections
##           SecTaskDifDifficult
##           DisplayHUD:RoadsectionRecStraight Sections
##           DisplayHUD:SecTaskDifDifficult
##           RoadsectionRecStraight Sections:SecTaskDifDifficult
##           DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult
##  Residual
##  Std.Dev. Corr
##  401.76
##  308.20   -0.097
##   95.06   -0.163 -0.070
##  167.65    0.571  0.018 -0.053
##  292.11   -0.244  0.015 -0.068 -0.080
##  228.24   -0.234  0.352  0.060 -0.320  0.025
##   73.40   -0.062 -0.203 -0.122 -0.242 -0.172 -0.140
##  122.10   -0.556 -0.107  0.043 -0.407  0.063 -0.104  0.042
##  762.72
## Num. levels: VP 24
##
## Sample avg. posterior predictive
## distribution of y (X = xbar):
```

```
##          Median    MAD_SD
## mean_PPD 1153.8141   34.1118
```

```
summary (MeanDur_stan, digits = 4)
```

```
## stan_lmer(formula = Mean_MS_Target ~ Display * RoadsectionRec *
##     SecTaskDif + ((Display * RoadsectionRec * SecTaskDif) | VP),
##     data = D1)
##
## Family: gaussian (identity)
## Algorithm: sampling
## Posterior sample size: 4000
## Observations: 986
## Groups: VP 24
##
## Estimates:
##                                                                  mean
## (Intercept)                                                    722.1088
## DisplayHUD                                                     521.7549
## RoadsectionRecStraight Sections                                133.3552
## SecTaskDifDifficult                                            138.9194
## DisplayHUD:RoadsectionRecStraight Sections                     135.6425
## DisplayHUD:SecTaskDifDifficult                                 140.9610
## RoadsectionRecStraight Sections:SecTaskDifDifficult            -13.3575
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult -187.8708
## sigma                                                          762.9942
## mean_PPD                                                      1153.7761
## log-posterior                                                -7188.9204
##                                                                  sd
## (Intercept)                                                    112.7021
## DisplayHUD                                                     117.1773
## RoadsectionRecStraight Sections                                101.9282
## SecTaskDifDifficult                                            106.9367
## DisplayHUD:RoadsectionRecStraight Sections                     160.7912
## DisplayHUD:SecTaskDifDifficult                                 154.7475
## RoadsectionRecStraight Sections:SecTaskDifDifficult            142.2877
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult 203.3832
## sigma                                                           18.2093
## mean_PPD                                                        34.5471
## log-posterior                                                   14.2730
##                                                                  2.5%
## (Intercept)                                                    503.8609
## DisplayHUD                                                     293.7517
## RoadsectionRecStraight Sections                                -66.5322
## SecTaskDifDifficult                                            -68.4178
## DisplayHUD:RoadsectionRecStraight Sections                    -183.4818
## DisplayHUD:SecTaskDifDifficult                                -156.1786
## RoadsectionRecStraight Sections:SecTaskDifDifficult           -291.3614
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult -580.5632
## sigma                                                          729.5375
## mean_PPD                                                      1085.5504
## log-posterior                                                -7217.4506
##                                                                  97.5%
## (Intercept)                                                    945.5456
## DisplayHUD                                                     759.6460
## RoadsectionRecStraight Sections                                332.4274
## SecTaskDifDifficult                                            350.3713
## DisplayHUD:RoadsectionRecStraight Sections                     445.6911
## DisplayHUD:SecTaskDifDifficult                                 438.0002
## RoadsectionRecStraight Sections:SecTaskDifDifficult            266.8509
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult 207.7813
## sigma                                                          800.3757
## mean_PPD                                                      1221.5217
## log-posterior                                                -7162.2051
#### Number of gaze switches
options (digits = 4)
```

```
NrGS_stan <-stan_glmer(GazeSwitch_Target ~ Display * RoadsectionRec * SecTaskDif +
               (Display * RoadsectionRec * SecTaskDif | VP) + (1 |Obs),
             family = poisson,
             data = D)

options (digits = 4)
print(NrGS_stan, digits = 4)

## stan_glmer(formula = GazeSwitch_Target ~ Display * RoadsectionRec *
##     SecTaskDif + (Display * RoadsectionRec * SecTaskDif | VP) +
##     (1 | Obs), data = D, family = poisson)
##
## Estimates:
##                                                                    Median
## (Intercept)                                                         1.9559
## DisplayHUD                                                         -0.1658
## RoadsectionRecStraight Sections                                    -0.2148
## SecTaskDifDifficult                                                 0.0180
## DisplayHUD:RoadsectionRecStraight Sections                         -0.0902
## DisplayHUD:SecTaskDifDifficult                                     -0.1998
## RoadsectionRecStraight Sections:SecTaskDifDifficult                -0.0058
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult -0.0081
##                                                                    MAD_SD
## (Intercept)                                                         0.0798
## DisplayHUD                                                          0.0836
## RoadsectionRecStraight Sections                                     0.0565
## SecTaskDifDifficult                                                 0.0519
## DisplayHUD:RoadsectionRecStraight Sections                          0.1009
## DisplayHUD:SecTaskDifDifficult                                      0.0796
## RoadsectionRecStraight Sections:SecTaskDifDifficult                 0.0748
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult  0.1152
##
## Error terms:
##  Groups Name
##  Obs    (Intercept)
##  VP     (Intercept)
##         DisplayHUD
##         RoadsectionRecStraight Sections
##         SecTaskDifDifficult
##         DisplayHUD:RoadsectionRecStraight Sections
##         DisplayHUD:SecTaskDifDifficult
##         RoadsectionRecStraight Sections:SecTaskDifDifficult
##         DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult
##  Std.Dev. Corr
##  0.069389
##  0.369925
##  0.331347 -0.585
##  0.107656  0.018 -0.081
##  0.085859  0.026  0.154 -0.096
##  0.264036 -0.436  0.470  0.135  0.052
##  0.115759  0.314 -0.125  0.271  0.022  0.091
##  0.054334 -0.129  0.039 -0.223 -0.101  0.006 -0.106
##  0.063984  0.052 -0.019  0.212 -0.077  0.028  0.050 -0.125
## Num. levels: Obs 1039, VP 24
##
## Sample avg. posterior predictive
## distribution of y (X = xbar):
##          Median MAD_SD
## mean_PPD 5.9509 0.1070

summary (NrGS_stan, digits = 4)

## stan_glmer(formula = GazeSwitch_Target ~ Display * RoadsectionRec *
##     SecTaskDif + (Display * RoadsectionRec * SecTaskDif | VP) +
##     (1 | Obs), data = D, family = poisson)
##
```

```
## Family: poisson (log)
## Algorithm: sampling
## Posterior sample size: 4000
## Observations: 1039
## Groups: Obs 1039, VP 24
##
## Estimates:
##                                                                  mean
## (Intercept)                                                        1.9530
## DisplayHUD                                                        -0.1655
## RoadsectionRecStraight Sections                                   -0.2161
## SecTaskDifDifficult                                                0.0174
## DisplayHUD:RoadsectionRecStraight Sections                        -0.0915
## DisplayHUD:SecTaskDifDifficult                                    -0.2004
## RoadsectionRecStraight Sections:SecTaskDifDifficult               -0.0052
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult    -0.0099
## mean_PPD                                                           5.9523
## log-posterior                                                   4744.1974
##                                                                  sd
## (Intercept)                                                        0.0821
## DisplayHUD                                                         0.0848
## RoadsectionRecStraight Sections                                    0.0573
## SecTaskDifDifficult                                                0.0533
## DisplayHUD:RoadsectionRecStraight Sections                         0.1005
## DisplayHUD:SecTaskDifDifficult                                     0.0816
## RoadsectionRecStraight Sections:SecTaskDifDifficult                0.0745
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult     0.1158
## mean_PPD                                                           0.1079
## log-posterior                                                     32.2049
##                                                                  2.5%
## (Intercept)                                                        1.7885
## DisplayHUD                                                        -0.3336
## RoadsectionRecStraight Sections                                   -0.3300
## SecTaskDifDifficult                                               -0.0901
## DisplayHUD:RoadsectionRecStraight Sections                        -0.2901
## DisplayHUD:SecTaskDifDifficult                                    -0.3624
## RoadsectionRecStraight Sections:SecTaskDifDifficult               -0.1492
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult    -0.2474
## mean_PPD                                                           5.7382
## log-posterior                                                   4684.1954
##                                                                  97.5%
## (Intercept)                                                        2.1096
## DisplayHUD                                                        -0.0006
## RoadsectionRecStraight Sections                                   -0.1066
## SecTaskDifDifficult                                                0.1207
## DisplayHUD:RoadsectionRecStraight Sections                         0.1026
## DisplayHUD:SecTaskDifDifficult                                    -0.0380
## RoadsectionRecStraight Sections:SecTaskDifDifficult                0.1422
## DisplayHUD:RoadsectionRecStraight Sections:SecTaskDifDifficult     0.2124
## mean_PPD                                                           6.1655
## log-posterior                                                   4809.3059
```