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Motorcyclists' Preventive Riding and Visibility Through Intersections - A Qualitative Video Analysis

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This study examines the visibility and preventive riding of motorcyclists at intersections, focusing on how these factors affect traffic safety. The research was conducted with a 30-minute driving route involving 62 motorcyclists, divided into three groups: Novice, Experienced Riders, and Professionals, based on their riding experience and driving competence, in varied traffic conditions. The study is divided into three main parts: visible positioning, preventive riding, and attention and readiness at intersections. Our findings reveal significant weaknesses in preventive riding at intersections, safety gaps in attention and readiness at intersections, and that motorcyclists can make themselves more visible to other road users at intersections, especially by giving other road users enough time to notice them. Preventive riding is an important part of defensive driving that is not well described in the literature. In this study, preventive riding is described and conceptualized to make it easier to recognize the degree of preventive riding in a driver. In the discussion, we employ the Bowtie model from safety theory as a framework to contextualize everyday driving behaviors within a safety perspective. This study demonstrates substantial safety potential in everyday driving practices. The research was conducted using eye-tracker cameras and analyzed and discussed using a driving process model. This study can provide important contributions to driver training, evaluation, curricula, and regulations for traffic education, as well as for refresher courses.

Keywords: Eyetracking, motorcyclists, fixation points, safe riding, preventive riding, proactive barriers, visibility, readiness, defensive driving, attention and decision, hazard zone

1. Introduction

Motorcyclists constitute a significant high-risk group in road traffic, as reflected in accident statistics and research literature. According to Iversen and Njå (2022), motorcyclists in Norway are particularly vulnerable in traffic situations involving intersections and curves. This report aims to highlight the various risk factors motorcyclists encounter, as well as the strategic and tactical choices they make to prevent conflicts and reduce risk when riding through intersections. Riding through intersections is one of the most challenging situations for motorcyclists. In such scenarios, the motorcyclist must be especially vigilant of other road users and potential hazards. Iversen and Njå (2022) emphasize that motorcyclists need to develop effective strategies to prevent conflicts and risks when approaching and navigating through intersections. The development of motorcycle accidents poses a challenge to road safety and the Vision Zero initiative. According to Iversen and Njå (2022), there has been an increase in the number of registered medium and heavy motorcycles, as well as an increase in the number of accidents involving such vehicles. Previous studies have shown that rider skill, experience with the vehicle, and riding experience are important factors influencing accident risk (Høye, 2017; Høye et al., 2016). To achieve a reduction in the number of accidents, targeted efforts against high-risk factors and vulnerable road user groups are therefore necessary. Previous research (Høye, 2017; Høye et al., 2016) has shown that motorcycle accidents differ from those involving other vehicles, with driver competence—covering traffic skills, vehicle handling, and overall riding experience—being a critical factor. This highlights the need to consider how driver skills interact with road design and traffic conditions. The study employs video analysis to shed light on these issues.

Nord University, in collaboration with SINTEF and commissioned by the Norwegian Public Roads Administration, conducted a study in 2024 focusing on motorcyclists' decision-making to enhance safe riding at intersections and on curves. The study was expanded in 2024 to include more participants and new research questions (Wigum et al. 2023; Wigum et al. 2025). The video analysis using Eyetracker describes the experienced curriculum (Goodlad, 1979) and learning outcomes (Tang and Biggs, 2011) of the traffic education for the students, several years after they obtained their motorcycle licenses. It is important to understand this experienced curriculum so that we can guide teaching, evaluation, and curriculum and regulations in the right direction towards the Vision Zero goal for traffic safety. Additionally, it is crucial to compare the practices of professional riders with those of experienced and novice riders to identify what the professionals do well, so that we can learn from it.

2. Theoretical framework

2.1. *Bowtie model*

To discuss and analyze the risks associated with driving at intersections, we have chosen to use the Bowtie model or diagram (Rausand and Utne, 2009) as our theoretical framework. The purpose of using the Bowtie model, which highlights the importance of proactive safety barriers, is to place various types of everyday motorcycle riding into a safety perspective and safety culture, like what is seen in aviation and offshore oil extraction. This will demonstrate how safety theory can explain different safety levels in traffic. For driving in traffic, such a Bow-tie diagram is significant in emphasizing that preventive measures are crucial for achieving the Vision Zero goal, and that driving in traffic can be made safer than it is today.

A Bowtie diagram (Rausand and Utne, 2009) can illustrate and highlight key aspects of risk. See Figure 1. A Bowtie diagram highlights known and unknown threats and consequences of an unwanted event and illustrates how various barriers can prevent accidents beforehand (proactive barriers) and mitigate or limit damage afterward (reactive barriers).

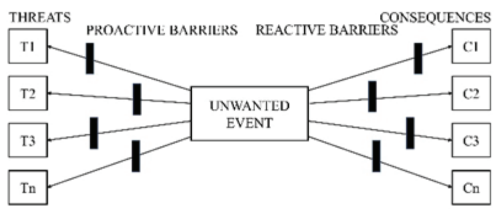

Fig. 1. Bowtie diagram

For example, a motorcyclist who enters an intersection without taking any measures to avoid being hit by traffic that does not yield the right of way is exposed to a "Threat" where the rider has no "Proactive barriers" for an "Unwanted event." If the rider does not use safety equipment, the "Reactive barriers" will be missing, resulting in greater consequences. The choice of speed can also affect the outcome (Consequences). The Bowtie model helps us identify known and unknown threats that can arise while driving in traffic and emphasizes the importance of the driver taking responsibility to ensure robust barriers against these threats. In this study, we analyzed motorcyclists' driving through intersections in situations where they do not have the right of way but may be exposed to a collision with a road user who does not yield. The driving behaviors were analyzed and categorized into three categories: positioning, preventive driving, and attention. The results for the three categories are presented as dimensions, which describe the level of the barrier intended to prevent an unwanted incident from occurring.

2.2. *The driving process model*

The driving process (Moe, 2021), which is an established model in driver training in Norway, was used as an analytical tool to examine and discuss driving in traffic. The driving process (Moe, 2021) is a simplified model for analyzing and understanding driving behavior based on research in neurobiology and psychology. The model can simplify the assessment of driving by breaking down the process into four main components: sensing, perceiving, deciding, and acting. Additionally, the model is flexible as it can incorporate relevant content to be investigated, such as knowledge, attitudes, strategies, etc. This makes it possible to evaluate each part of the driving process individually, which can provide a more detailed understanding of the driver's behavior and decision-making in traffic.

3. Methods

3.1. *Analysis conducted with eyetracker*

This study is part of a report that presents and examines motorcyclists' preventive riding and visibility at intersections. The rider's observation and riding were filmed using Tobii Eye-tracking glasses adapted to the motorcyclist's helmet. The EyeTracker glasses have four eye cameras that record the rider's observations during riding, and a scene camera that films the road and traffic in the direction the glasses are pointed. They also include audio recordings. We used the raw data from the Eye-Tracker system to map the driver's saccadic eye movements, which can provide insights into the driver's cognitive processes.

The forward-facing camera provides information about the rider's position, speed adaptation, and adjustment to other traffic. Sometimes, we could also observe the motorcycle's speedometer and how the rider operates the throttle and front brake, depending on how the camera angle could capture these movements.

3.2. *Description of the riding route*

The riding route was 30 minutes long and included riding in busy intersections, exits, and roundabouts, as well as riding on country roads in the middle part of the route. Riding in different types of intersections was assessed throughout the entire route, focusing on traffic situations where the rider does not have to yield. For example, when the motorcyclist is inside the roundabout and other road users must yield as indicated by signs, when riding on a priority road, or when riding on a road where other road users must yield to the motorcyclist as they come from a parking lot or exit.

3.3. *Participants and the three driving groups*

The 62 participants were divided into these three groups based on their experience level and formal and informal education or work with motorcycle riding in traffic and on track.

Group 1: Novices - Motorcyclists with less than three years of riding experience who use motorcycles for leisure and utility riding.

Group 2: Experienced Riders - Motorcyclists with more than three years of riding experience who regularly use motorcycles for leisure and utility riding.

Group 3: Professionals - Motorcyclists with extensive professional experience, such as police officers who ride motorcycles for emergency response, motorcycle traffic instructors, and examiners for motorcycle driving tests, as well as instructors at motorcycle driver development courses, specifically for track riding.

Groups 1 and 2 were recruited through advertisements on social media, and they were assigned to riding groups based on their motorcycle riding experience. While Group 3 was handpicked based on our knowledge that they possess special riding skills with motorcycles in traffic and/or on track.

3.4. The article authors

The researchers who conducted the analysis are employed at the traffic instructor education program at Nord University (Nord University, 2024). They train Norway's motorcycle instructors and contribute to parts of the education for driving test examiners at the Norwegian Public Roads Administration. The researchers have extensive experience in training for all A-license classes. Two of the researchers have also worked as a driving test examiner for the motorcycle driving test.

3.3. Analysis

In our work to understand the data material from video recordings with the Eye-Tracker, we used principles from Grounded Theory (Strauss and Corbin, 1998) to develop categories, and the driving process model (Moe, 2021) from the Norwegian driver training program to analyze driving in traffic. To develop categories and coding, we used the comparative method (Strauss and Corbin, 1998) to compare drivers' driving styles (Dimensions). Within each category, various dimensions (Strauss & Corbin, 1998) were further explored to understand the meaning content of the data collection. For instance, we analyzed speed selection when approaching an intersection to determine whether the intention was to proceed quickly or ensure a safe drive. The driving process model (Moe, 2021) was employed as an analytical tool to examine driving behavior in traffic. We focused on directly observable data. This included specific actions such as speed selection and positioning when approaching busy intersections. We examined when and how traffic is observed, the timing of decisions to proceed, follow-up checks on assessments, and the safety margins maintained by the driver. The different driving profiles were then developed into the three categories with their dimensions in this study. One researcher was primarily responsible for mapping all 62 drivers, while another researcher reviewed a random sample to ensure consistent interpretation of the results.

3.4. Ethics

All participants in the study were thoroughly briefed on the project's aims and potential risks. Each participant received a written consent form prior to their involvement. The project was approved by the Norwegian Agency for Shared Services in Education and Research (SIKT, 2023), formerly known as the Norwegian Centre for Research Data (NSD), in accordance with the General Data Protection Regulation.

4. Results

In the development of categories and dimensions (See Table 1.), available and relevant empirical data were used. Curriculum for class A (NPRD 2016), Road Traffic Act (Lovdata a, 2025) and the traffic training regulations (Lovdata b, 2025 were used. These documents were used to compare observed behavior against expected behavior based on the governing documents. Positioning, speed, and observation were given significant attention to analyzing each rider's behavior against the expected behavior.

Table 1 below shows the three categories 1. Visible Positioning, 2. Preventive riding, 3. Attention and Decision Timing through Hazard Zones and identified to each rider’s behavior against the expected behavior. The stretch where there is a risk of collision is referred to as the danger or hazard zone.

Categories	Dimensions
1. Visible Positioning The motorcyclist’s visible position (not speed) in typical intersection situation where accidents often occur	A: Visible to road users with the right of way B: Less visible positioning
2. Preventive riding	A: Preventive B: Not preventive (Just riding) C: Creates risky situation
3. Attention and Decision. Attention and Decision Timing through Hazard Zones	A: Does not trust road users in the hazard zone B: Trusts road users who indicate they will stop in the hazard zone C: Uncritical riding

Table 1. The Three Categories with Dimensions.

The three categories 1. Visible Positioning, 2. Preventive Riding, and 3. Attention and Decision with their dimensions will be explained below.

4.1. Visible position

The "Visible Position" category addresses how motorcyclists make themselves visible to other road users through their positioning when approaching intersections. In this context, visibility means that the motorcyclist has an unobstructed line of sight to the road user who must yield. We do not consider the duration of visibility to other road users in this category; time is included as a factor in the next category (2) concerning preventive riding.
Figure 1 presents the results of the illustrative explanation for the three groups. Dimension A (green in figure 1) represents motorcyclists who “ride with a position that can make them visible to road users who is obliged to give way to the rider”. Dimension B (orange in figure 2) are motorcyclists who “ride with a position that is not very visible”.

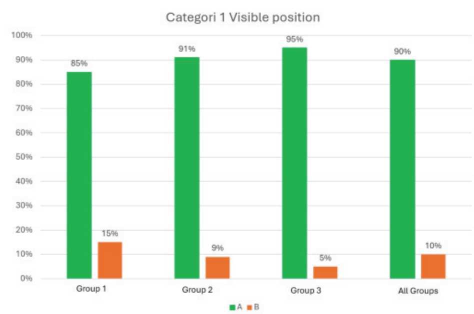

Fig.2. Results for Category 1. Visible positioning at intersections with the two dimensions A and B, for the three groups 1, 2, and 3, and the summarized result (All groups) for all 62 riders.

Group 1 Novices: (A) 85% of these riders position themselves to be visible to road users who must yield, ensuring an unobstructed line of sight and increasing safety at intersections. (B) 15% position themselves less visibly, potentially increasing accident risk.
Group 2 Experienced Riders: (A) 91% of these riders position themselves to be visible to road users who must yield, showing awareness of visibility in traffic. (B) 9% position themselves less visibly, indicating room for improvement.
Group 3 Professionals: (A) 95% of these riders position themselves to be visible to road users who must yield, demonstrating a strong understanding of visibility's importance. (B) 5% position themselves less visibly, showing some room for improvement.
All Groups (62 riders): (A) 90% of all riders position themselves to be visible to road users who must yield, indicating most riders are aware of visibility in traffic. (B) 10% position themselves less visibly, suggesting some riders can improve their visibility to enhance safety

4.2. Preventive riding

This category 2. examines the extent to which motorcyclists avoid (prevent) or create dangerous situations at intersections, in scenarios where other road users must yield to the motorcyclist. These situations include riding on a priority road where oncoming traffic must cross the road, or intersections where traffic from the side must enter the priority road. We also analyzed how the motorcyclist interacts with other road users who must yield to the motorcyclist before and within roundabouts, and when passing exits and parking lots.

Figure 3 shows the results of the illustrative explanation for category 2., Preventive riding for the three dimensions (A, B and C). Dimension A (green in figure 2) are the motorcyclists who “ride preventively”. Dimension B (orange in figure 2) are those who “does not ride preventively or just ride”. Dimension C are those who “creates dangerous situations and makes it difficult for other road users to notice them”.

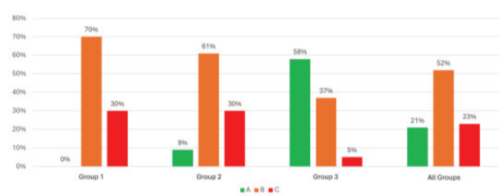

Fig. 3. Results for Category 2. Preventive riding at intersections with three dimensions, A, B and C for the three groups and all groups.

None of the riders in Group 1 Novices (A) ride preventively at intersections where other road users must yield. Although there are tendencies towards preventive riding in some traffic situations, it does not qualify as a preventive riding style. (B) 70% of the riders in Group 1 do not ride preventively; they "just ride" and handle situations as they come. Additionally, (C) 30% of the riders create more dangerous situations at intersections, making it harder for other road users to notice them. In Group 2 Experienced Riders: (A) 9% of the riders ride preventively at intersections. (B) 61% do not ride preventively and handle situations as they come. (C) 30% create more dangerous situations, making it harder for other road users to notice them. In Group 3 Professionals: (A) 58% of the riders ride preventively at intersections. (B) 37% do not ride preventively, and (C) 5% create more dangerous situations, making it harder for other road users to notice them. Results for all groups (62 riders): (A) 21% ride preventively. (B) 52% do not ride preventively. (C) 23% create dangerous situations, making it difficult for other road users to notice the motorcyclist.

4.3. Riders' attention and decision

This category 3. Riders' attention and decision examines how motorcyclists interact with other road users who must yield to them at various types of intersections, considering the vulnerability of motorcyclists to accidents at intersections. It focuses on how the rider observes other road users and maintains readiness through the intersection, in situations where there is a risk of collision if the other road user fails to yield. The stretch where there is a risk of collision is referred to as the danger zone. Readiness is defined as an adequate combination of speed adjustment, positioning, and mental and/or physical braking readiness. The three dimensions (A, B and C) are the following: (A): "The motorcyclist does not trust road users who are in the motorcyclist's danger zone", (blue in figure 4). (B): The motorcyclist "relies on road users who indicate to stop in the danger zone", (orange in figure 3). (C): "The motorcyclist rides uncritically through the danger zone", (green in figure 4).

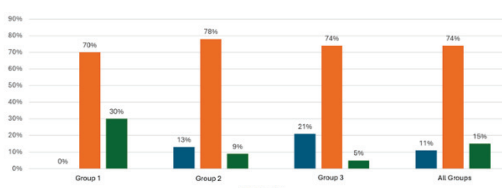

Fig. 4. Results for Category 3. Rider's attention and decision at intersections with three dimensions, A, B and C for the three groups and all groups. Results for Group 1 Novices, consisting of riders with less than three years of riding experience who use motorcycles for leisure and utility riding, show that (A) 0% do not trust road users in the motorcyclist's danger zone, (B) 70% trust road users who indicate they will stop in the danger zone, and (C) 30% ride uncritically through the danger zone. None of the riders in Group 1 ride with full attention and readiness through the entire danger zone at intersections. Although some riders observe and are prepared initially, their riding does not qualify for dimension A. Dimensions A and B are similar, except for the timing of the decision on when it is clear or safe to proceed. Results for Group 2 Experienced Riders, consisting of riders with more than three years of riding experience who regularly use motorcycles for leisure and utility riding, show that (A) 13% do not trust road users in the motorcyclist's danger zone and ride with full attention and readiness through the entire danger zone at intersections. (B) 78% trust road users who indicate they will stop in the danger zone but end their readiness too early and (C) 9% ride uncritically through the danger zone. In Group 2, 13% ride with full attention and readiness through the entire danger zone at intersections. 78% trust other road users who indicate they will stop but end their readiness too early. 9% ride uncritically through the danger zone. Results for Group 3 Professionals, consisting of riders with extensive professional experience on motorcycles, such as police officers, driving test examiners, driving instructors, and instructors in advanced driving courses, show that (A) 21% do not trust road users in the motorcyclist's danger zone, (B) 74% trust road users who indicate they will stop in the danger zone, and (C) 5% ride uncritically through the danger zone. Results for all groups (62 riders) show that (A) 11% do not trust road users in the motorcyclist's danger zone, (B) 74% trust road users who indicate they will stop in the danger zone, and (C) 15% ride uncritically through the danger zone.

5. Discussion

5.1. Visible position

The results for visibility positioning show that all groups drive with good visibility, as only 10% of all groups drive with low visibility. Group 1, the novices, have the lowest percentage of visible drivers at 85%, which is noteworthy considering they recently completed their traffic training. Group 2, the experienced drivers, have slightly higher visibility at 91%, and Group 3, the professionals, drive with 95% visibility. The 5% of professionals driving with low visibility can be explained by the fact that this group includes drivers with both formal and informal education or work experience in motorcycle riding, either in traffic or on tracks. From a safety perspective, using a Bowtie model (Rausand and Utne, 2009), these results indicate that increasing visibility in traffic is a barrier that can be improved to prevent accidents. What was surprising in this study was that those who drove recklessly in the other categories did quite well in terms of visibility in traffic. It wasn't visibility that was the problem, but speed adaptation, especially speed adaptation related to preventive driving, which is category 2.

5.2. Preventive riding

This study shows that all three driver groups have significant deficiencies in preventive driving. In Group 1, the novices, none drive preventively, with 30% creating dangerous situations and 70% driving through intersections without taking particular risks into account. In Group 2 experienced drivers, only 9% drive preventively, 61% just drive, and 30% create dangerous situations. For Group 3 professionals, 58% drive preventively, 37% just drive, and 5% create dangerous situations. Only 21% of all drivers in this study drive preventively, but the professionals drive much more safely than the novices and experienced riders. The novices and experienced riders hardly drive preventively at all. This can perhaps be explained by the fact that many of the professionals have education and training in traffic driving, and that some of them lack this. From a safety perspective Bowtie model (Rausand and Utne, 2009), avoiding accidents or ensuring barriers are in place to prevent unwanted incidents is crucial for maintaining safety effectively. These high numbers suggest that preventive driving may be a weakness in driver training and evaluation during the driving test, as well as in curricula and regulations for traffic education. Therefore, traffic education should implement measures that promote risk thinking in driving, such as practicing commentary driving and using risk theory like Bowtie. See, for example, Bogfjellmo and Størseth (2023), which highlights this

5.3. Riders' attention

Few drivers are critical of traffic that must yield to motorcyclists throughout the entire danger zone. None in Group 1, the novices, and only 9% in Group 2, the experienced drivers, are critical. Among the professionals, only 58% remain vigilant and ready throughout the entire stretch where there is a risk of being hit if someone fails to yield. However, more drivers are attentive and vigilant in the initial part of the danger zone but tend to trust the traffic once it stops or they make eye contact. These drivers are cautious but may lack knowledge of how to stay prepared throughout the entire danger zone to avoid being hit. Uncritical driving through the danger zone can pose a risk if the motorcyclist is not noticed by other traffic. A significant proportion of drivers drive uncritically through the danger zone. 30% of the novices in Group 1 drive uncritically through the danger zone, and 5% of the experienced drivers also drive uncritically through intersections. These drivers lack barriers that ensure they avoid accidents if someone overlooks the motorcyclist.

6. Implications

Training should emphasize visibility and vigilance in traffic through practical exercises and theoretical instruction. Experienced motorcyclists show better preventive riding skills, so training should include experiential learning and advanced courses. Continuous education and refresher courses are crucial. Campaigns and informational initiatives can raise awareness about preventive riding and vigilance, contributing to safer traffic.

7. Conclusion

From a safety perspective shown with the Bowtie model (Rausand and Utne, 2009), the findings in this study indicate that motorcyclists lack barriers to avoid accidents at intersections. All groups generally have good visibility, with novices at 85%, experienced drivers at 91%, and professionals at 95%. Improving visibility can help prevent accidents. Significant deficiencies in preventive driving exist across all groups, with only 21% of all drivers practicing it, suggesting a need for better training and evaluation. Few drivers are vigilant throughout danger zones, with only 58% of professionals maintaining vigilance. Motorcyclists should learn to be critical of other road users and remain vigilant throughout the entire danger zone where they might be hit at intersections. They must learn not to trust other road users, even if they make eye contact.

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