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# Visual-aid effects on novice drivers of Powered Two-Wheeled Vehicles on a virtual simulator

Obaida Alrazouk<sup>1</sup>, Amine Chellali, Lamri Nehaoua, and Hichem Arioui

**Abstract**—Immersive VR technologies offer simulation and testing tools by recreating dangerous real-world scenarios in a safe virtual environment while providing participants with a first-person experience. The adaptation of these systems as driving simulators or virtual training systems is increasing as the demand for safe driving increases. It is known that driving is a visually demanding process, and while the exact mechanism that connects steering to gaze direction is not known, some visual steering strategies, such as the tangent point, have already been identified for cars. In this paper, we aim to investigate the impact of providing novices with a tangent point strategy-based visual aid on performance, driving behavior, and eye behavior when driving a Powered Two-Wheeled Vehicle (P2WV) in an immersive virtual environment, and how novices compare to expert drivers. For that purpose, a VR environment with a physical motorcycle platform was developed. Novices and experts were recruited to perform driving tests on this setup. Their driving data, in addition to their eye data, were recorded and analyzed, and some differences were found. These findings and observations will serve as guidelines for future work.

## I. INTRODUCTION

Road accidents have decreased significantly during the past several decades due to the fast adaptation of new road safety regulations and equipment. However, human error is still the most significant contributor to these accidents. Vehicles, particularly Powered Four-Wheeled Vehicles (P4WV), have gradually adopted new safety technologies that passively or actively help, assist, or alarm the driver in difficult situations. Despite these improvements and the decreasing number of accidents, the situation is still alarming and affects both developed and developing countries, the latter more than the former.

Unlike P4WV, P2WV have not yet seen the adoption of such systems, most likely because of the highly dynamic nature of these vehicles and the limited space they have onboard. Motorists and other Powered Two-Wheeled Vehicles (P2WV) riders are still among the most vulnerable road users. In 2019 ONISR published a study [1] showing that in France, P2WV accidents are 22 times more fatal than P4WV, accounting for 23% of all traffic fatalities. Most single P2WV accidents are due to problems maneuvering curves. Among these accidents, 18% of the drivers are still novices.

While executing a curve maneuver, the driver is expected to foresee the road curvature while deciphering visual clues and responding by adapting his speed, acceleration, and steering angle. In addition to safety requirements such as staying in the traffic lane, it is necessary to maintain the

ability to adapt the trajectory by tightening or widening it to avoid possible obstacles on the roadway.

Driving is a process that depends mainly on visual perception. This led many researchers to study eye movements while driving [6], [18], [19] and [20]. This can help identify useful positions or sequences in the visual scene that might give an insight into the underlying cognitive processes of the experienced driver. The results have been used to construct a visual-steering system based on the tangent point of the road [20], build driver warning systems [4] and [5], and teach novices about important road landmarks, visual cues, and maneuvering strategies in order to enhance their capabilities and increase their safety.

The utilization of virtual simulators in the past few decades has grown substantially as a lab-controlled alternative for real-world scenarios. Now novices can benefit from training experiences in a safer environment and execute maneuvers that are deemed to be too dangerous to execute on real roads.

While most research focused on experts driving a P4WV to learn their techniques and model their behavior, not much has been done in P2WV, especially to apply these findings to novices and check their advantages or disadvantages. This work investigates the effects of visual aid for novices on their driving performance and behavior while executing a driving test in a virtual environment. The research questions are as follow:

- Does a visual aid affect the behavior and the performance of novice drivers?
- If so, how does it compare to experts?

To investigate these questions, a VR environment has been developed and linked with a basic motorcycle platform that allows the execution of simple movements (steering, braking, and accelerating). The system allows for maneuvering a virtual motorcycle while recording the gaze data of the participant and other vehicle-related data. A visual aid based on the tangent point model, was also displayed to the participants depending on the experimental conditions.

## II. BACKGROUND

### A. Driver assistance systems

The need for safer driving motivated the research for systems to aid drivers and decrease accidents. These systems can be categorized into two groups (according to their impact on the vehicle input): active and passive systems. Active systems act directly on the vehicle's input to automatically prevent accidents (known in the literature as Advance Driver Assistance Systems (ADAS) ). Passive systems modify the

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driver's behavior through his senses, such as notification and warning systems.

1) *Active systems*: Represented by ADAS systems, they are used to help the driver or to automate some challenging tasks. Some are critical to safety, while others provide convenience, increase efficiency, or comfort [2]. In general, these systems act on the vehicle inputs such as braking and steering and modify the vehicle's dynamics in difficult situations (such as anti-slip systems), prevent the vehicle from flipping on sudden braking, or in some typical situations, make driving more straightforward (such as cruise control). However, ADAS systems must not be regarded as a substitute for drivers but rather as a co-driver, even if direct involvement in some of the driving tasks is not required [3].

2) *Passive systems*: The purpose of these systems is to track the driver's status and suggest appropriate assistance for safer and more comfortable driving. Such systems provide constant feedback for the driver about the status of the road and the vehicle, track the driver's status and attentiveness, provide warnings for the driver in dangerous situations, and so on. According to their function, there are several names for such systems like driver's inattention monitoring, accident prediction, driver's drowsiness, and sleepiness monitoring. The main difference between these passive systems and active systems is that the passive systems "asses" and "understand" the driver's situation, and the active systems "act" to help the driver and prevent dangerous situations. Many of these systems that aim to track a driver's status are vision-based systems that monitor some features or movements of the driver's face, and the majority focus on the eyes. Authors in [4] proposed a driver's alertness detection system based on the degree to which the driver's eyes are open or closed. Authors in [5] proposed an algorithm to analyze blink rate, duration, facial features, and head position for signs of drowsiness, such as yawning and sudden head nods. However, almost all the systems that use eye movement are used to detect some behavior of the driver. To the authors' knowledge, none has been proposed to draw the driver's attention to important positions on the road or trajectory correction. There is also not much research in the field of passive driver assistance or trajectory correction in motorcycles, at least in training scenarios.

### B. Eye tracking concepts

Vision is very important for humans as sensory input, as they are our window to the world. However, the eyes are not perfect. While we can see a wide angle of the visual field, the area we can see at once is only the part where the fovea is located. This only accounts for a maximum of 2 degrees of the visual field. This is why humans tend to move their eyes, so the object of interest falls on the fovea to capture as much information of it as possible. In most everyday life tasks, the gaze is a crucial component in the action control process. Humans efficiently move their eyes to foveate targets and relate or link visual cues to perception and action. Studies on eye movement in everyday tasks, such as washing hands, preparing a sandwich, and driving, have revealed a common

pattern: gaze significantly targets locations and objects relevant to the task, with the gaze happening before the action by about 1s [6]. This strong attraction of the gaze cannot result from how much an object outstands from its environment "visual saliency", but from information about the task and its steps [7]. In addition to these "guiding fixations" [8], there are some occasional look-ahead fixations that preview information about locations and objects relevant for future actions [9]. It has been shown that capturing the eye position can give an insight into the thought process [10], [11] and [12]. The main eye features, generally studied when it comes to attention and the thought process, are derived from the eye position [13]. Other important features not related to the position are pupil dilation and blinking, which are mainly used to study emotions. Fixation is one important feature. it is a position where the eye stops moving and "fix" its location for a duration of time. This period is believed to reflect the attention and stimulus processing time needed at that specific location. Another important feature is saccades. A saccade is a rapid eye movement between two positions (fixations), which also can reflect the shift of attention if it is intentional (controlled) or unintentional (reflex to visual stimulus). These features will serve as a basis for studying motorcyclists gaze behaviour while driving in our study.

### C. Steering behaviors when negotiating a bend

Two different steering behaviors can be observed when negotiating a bend [14]. The first one is 'racing' behavior where The rider moves from the outside edge of his lane to the inside bend curvature while approaching the apex point. Then he moves back to the outside edge. This behavior allows a faster and smoother way of negotiating bends at the expense of the visibility of the road. Typically this behavior is seen during on track races without traffic. The other behavior is 'safe trajectory' [15]. In this case, the rider tries to achieve a safer trajectory to minimize accidents and fatalities. Indeed, this behavior allows the rider to see the incoming way in the curve as much as possible and thus having more time to react to hazards. For left bends, when the rider approaches the bend, he maintains his position near the outside of the bend throughout the curve (while adjusting his speed after the apex). For right bends, the driver changes his position to the outside edge of the bend (left side) and maintains this position until passing the apex point. Then, he changes his position to the inside edge of the curve. Figure 1 illustrates this 'safe path' trajectory in both left and right bends. While this is not the fastest way to take the curve, it is the safest. This is why this approach is usually taught in driving schools, and it is more encouraged on real roads when traffic is an issue.

Riders tend to use similar strategies to the described 'racing' behavior [4], [16], [17]. However, all of these studies used static motorcycle simulators and acknowledged that the lack of physical fidelity of the simulator might have affected the driver's behavior. This issue was further investigated by [18]. It turns out that, with a direct steering approach, the drivers followed the 'race' behavior, and with counter-



Fig. 1: Safe trajectory for motorcycles

steering available in the dynamics of the simulator, they followed a trajectory close to the 'safe path'.

#### D. Visual steering models

The tangent point model, one of the most common visual steering models, was proposed by [20] as a steering strategy. The tangent point is the point of the road where the line of sight is tangential to the lane edge (which is why this point is called the tangent point) [19]. It has been illustrated [20] that the steering angle follows the gaze angle (the horizontal angle between the gaze and the heading of the vehicle), which shows the importance of the "tangent point" as a crucial feature that the drivers use in their visual guidance. Based on that, our work aimed to guide the riders gaze during driving so that it follows this tangent point model.

Passive assistance systems have existed for a while for P4WV. While techniques that utilize eye data already exist, they are primarily for checking drivers' status. However, regarding P2WV, despite some research on driver behavior changes, few studies have used eye metrics. Novice P2WV riders are still a main cause of traffic fatalities, especially when maneuvering a curve. Studies that link gaze behavior and steering angle have existed for a while, but very limited research has been done in P2WV. It has been shown that expert P4WV drivers share similar eye behavior and utilize the same key visual cues to help navigate and steer the vehicle. As far as the authors are aware, none has attempted to modify the eye behavior of novices to verify if they enhance their driving performance. We test this hypothesis by introducing a visual aid in a VR environment in the shape of a ring on the tangent point of the road and instruct them to follow it using their eyes and monitor the performance difference.

### III. METHODS

#### A. Working Hypotheses

The main hypothesis is that gaze direction affects the vehicle trajectory, and by modifying the first, we could improve the second. To test this hypothesis, and based on our review of the literature, we have designed a visual aid

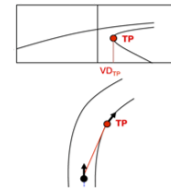


Fig. 2: Tangent point model [21]

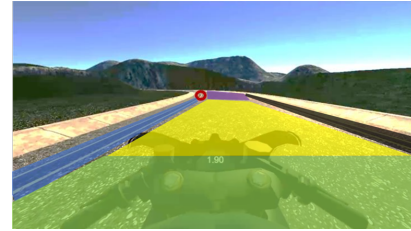


Fig. 3: Visual field Zone split, red: near tangent point, blue: near left lane, black: near right lane, green: road near, yellow: road ahead and purple: road far ahead

to guide the riders gaze during driving so that it follows the tangent point model. We have then conducted a user study to investigate the impact of this aid on novice riders behavior and on their driving performance.

#### B. Participants

Thirty volunteers (25 males, 5 females) from the university's staff and students participated in this study ( $N=30$ ). All of the participants had normal or corrected to normal vision. Eleven of them wore their prescription lenses during the experiment. Twenty-five of them drive cars with experience of ( $M = 14.4, SD = 12.1$ ) years. 29 on them had experience ( $M = 24.1, SD = 13.6$ ) years driving a bicycle, and 8 had experience using motorcycles for ( $M = 10.3, SD = 12.3$ ) years, but only 4 of them uses motorcycles on a regular basis. Twenty-three participants have reported previous experience with 3D virtual environments. Among them, 23 reported previous experiences using a VR HMD, with 16 reporting usage of at least 10 minutes per session.

The participants were divided into two groups: novices (no experience with motorcycles,  $N = 22$ ) and experts (experience with motorcycles,  $N = 8$ ). The novices were then randomly divided into two groups, each asked to perform the experiment with one of the two experimental conditions. All participants gave informed consent before the experiment began.

#### C. Apparatus

For this experiment, we designed and developed a VR simulator and a fixed (no rolling action) physical platform to capture the user input (steering, throttle, brakes,...).

To achieve a higher level of immersion, a VR Head Mounted Display (HMD) HTC vive Pro Eye, was used to display the VR environment to the user and to track the position and rotation of the head thanks to optical elements that exist on the HMD. It also contains an eye tracking sensor. A bike frame was repurposed to serve as the way of

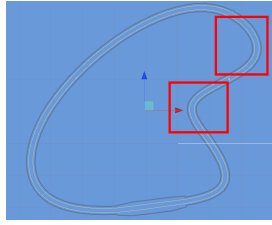


Fig. 4: Track used in the experiment

interaction with the VR environment. Two optical encoders were attached via custom 3D-printed pieces to measure the steering and throttle angles from the user. Send their data to an Arduino Mega card that, in turn, process the signals and sends angular positions to the PC application through Serial Port. In addition, two variable resistors were placed on each brake with the help of some 3D-printed pieces to capture braking input, which is in the same way fed to the PC application via the Arduino using the serial port link.

The Virtual environment itself was done using Unity game engine using some of the materials provided in Udacity open source driving simulator. The environment consists of a track with several left and right bends. Participants were seeing the environment from the first person perspective and were therefore able to see the motorcycle handlebar as well as the road. Depending on the experimental condition, a visual aid was also displayed. It intended to show the participants where to look according to tangent point model.

The application was run on a Windows 10 PC with Intel Xeon Silver 4214 CPU, NVIDIA RTX 2080 super GPU, with 32 GB of RAM. while performing the experiments, it produced around 120 FPS on average for normal driving and around 80 FPS on average for the visual aid drive.

#### D. Experiment task

Participants were asked to perform driving tests on the VR simulator. The participants were asked to drive the motorcycle as naturally as possible. No instructions on the vehicle speed during driving or steering behaviors were given. No instructions were given neither regarding the gaze behavior.

#### E. Experiment design

The experiment followed a between subjects design with three conditions: novices with visual aid (VF), novices without visual aid (NF) and experts (E). Four novices were excluded from the experiment for non-valid eye data or for crashing during the bend while doing the experiment.

#### F. Experiment procedure

First, each participant was assigned a unique identification number. Then he was shown a 150 seconds video that explains the objectives of the experiments and the steps to follow. After that, He was asked to answer the demographic questionnaire. Then he was placed on the motorcycle platform and then put on the VR headset. The eye tracking system was then calibrated for the participant's eyes. The



Fig. 5: Platform used in the experiment

participant performed a familiarization drive (on a different track than the one serving for the actual experimental drive). This permitted him to get familiarized with the controls and the environment. After that, he performed the test drive consisting of completing one full lap around the track. Only novices in the visual aid condition, was shown a visual aid in real time to guide their gaze while driving. These novices were also asked to rank how useful they found the visual aid.

#### G. Data collection and analysis

To make the comparisons, both eye and vehicle-related data were collected. During the experiment, the vehicle's location, rotation, velocity, acceleration, steering, throttling and braking were recorded. In addition, the location of the gaze origin and the direction vector were also recorded. In a later post-processing step, the distance from the left lane was calculated at each path point, and the gaze vector was intersected with the environment to find out the 3D location of the gaze. This was useful for simplifying the process of automatically assigning the gaze to the corresponding zone. The output of the post-process procedure is vehicle data plus eye data and corresponding zone, in addition to the lateral distance. After that, the data was post-processed using Python to change the layout and calculate the gaze percentage for each zone for each participant, plus the gaze angle and distance from the motorcycle. After that, the data was fed to SPSS to perform the statistical analyses.

It is also important to note that for the gaze part, we decided to split the road into six interest zones (any gaze point that lies outside of the road is not taken into account), near tangent point zone, near left lane zone, near right lane zone, the road near zone, the road ahead zone, and the road far ahead zone. Figure 3 illustrates these split zones. the purpose of these zones is to ease and automatically classify gaze points based on their 3D position, then the percentage of gaze points in each zone is counted and used later in the visual behavior analyses.

## IV. RESULTS

80% of VF reported the visual aid as useful and helped them during driving.

#### A. Visual aid effect on novices - left bend

For the entry phase: A Mann-Whitney U test indicated a statistically significant difference between NF and VF

regarding the mean percentage of gaze near left lane ( $U = 9, Z = -2.762, p = 0.006$ ). The difference in driving performance was not significant.

For the exit phase: The Mann-Whitney U test indicated a statistically significant difference between NF and VF on the mean horizontal distance between the gaze point and the tangent point ( $U = 14, Z = -2.31, p = 0.021$ ), the mean percentage of gaze near left lane ( $U = 7.5, Z = -2.898, p = 0.004$ ), and the mean percentage of gaze on the far road ( $U = 14.5, Z = -2.374, p = 0.018$ ).

There was no significant difference in terms of driving performance metrics.

### B. Visual aid effect on novices - right bend

For the entry phase: A Mann-Whitney U test showed a statistically significant effect of the visual aid on the average horizontal angle difference between the gaze point and the tangent point ( $U = 16, Z = -2.132, p = 0.033$ ), the mean horizontal distance of the gaze point ( $U = 16, Z = -2.286, p = 0.022$ ), the mean percentage of gaze near left lane ( $U = 19, Z = -1.952, p = 0.05$ ), the mean percentage of gaze near right lane ( $U = 11.5, Z = -2.547, p = 0.011$ ), and the mean percentage of gaze on the road far ahead ( $U = 17, Z = -2.144, p = 0.032$ ). As for performance, using the same test, the average lateral distance was significantly different ( $Z = -2.635, p = 0.008$ ).

For the exit phase: The Mann-Whitney U signed-rank test indicated a statistically significant difference between NF and VF on the average horizontal angle difference between the gaze point and the tangent point ( $U = 13, Z = -2.399, p = 0.016$ ), the mean percentage of gaze near left lane ( $U = 13.5, Z = -2.478, p = 0.013$ ), the mean percentage of gaze near right lane ( $U = 1, Z = -3.471, p < 0.001$ ), the mean percentage of gaze on the road ahead ( $U = 5, Z = -3.128, p = 0.002$ ), the mean percentage of gaze on the road far ahead ( $U = 6, Z = -3.112, p = 0.002$ ). No difference in terms of driving performance was significant.

### C. Experts vs novices - left bend

1) *Experts vs. novices without visual aid:* For both the entry and exit phases, the Mann-Whitney U test showed no statistically significant difference between experts and novices without a visual aid regarding behavior and performance.

2) *Experts vs. novices with visual aid:* For the entry phase, the Mann-Whitney U test showed a statistically significant difference between experts and novices with a visual aid in the mean percentage of gaze near left lane ( $U = 3, Z = -2.771, p = 0.007$ ), the mean percentage of gaze on the road ahead ( $U = 8, Z = -2.075, p = 0.038$ ). No difference in terms of performance was significant.

For the exit phase, the Mann-Whitney U test showed no statistically significant difference between experts and novices with a visual aid regarding behavior and performance.

### D. Experts vs novices - right bend

1) *Experts vs. novices without visual aid:* For the entry phase, the Mann-Whitney U test showed a statistically significant difference between experts and novices without a visual aid in the average lateral distance in bend entry ( $U = 4, Z = -2.429, p = 0.015$ ). The same test indicated no significant difference in terms of gaze behavior.

For the exit phase, the Mann-Whitney U test indicated a statistically significant difference between experts and novices without a visual aid in the percentage of gaze points near the right lane ( $U = 6, Z = -2.146, p = 0.032$ ), in the average steering angle ( $U = 4, Z = -2.429, p = 0.015$ ).

2) *Experts vs. novices with visual aid:* For the entry phase, the Mann-Whitney U test showed a statistically significant difference between experts and novices with a visual aid in the mean percentage of gaze near the right lane ( $U = 4, Z = -2.432, p = 0.015$ ). No significant difference in terms of performance was found.

For the exit phase, the Mann-Whitney U test showed a statistically significant difference between experts and novices with a visual aid in the mean percentage of gaze in the road ahead ( $U = 3, Z = -2.586, p = 0.01$ ). No difference in terms of performance was significant.

### E. Discussion

While most novices reported that the visual aid helped them during driving, there was no significant difference in driving performance on the left-bend scenario. However, on the more challenging right bend, there was a significant difference in average lateral distance in the entry phase, where the distance from the left lane dropped from ( $MDN = 16.56m$ ) in novices without visual aided to ( $MDN = 15.99m$ ) in novices with visual aided, which was very close to the lateral distance of experts in the same scenario ( $MDN = 16.04m$ ). This suggests the improvement of the novices' trajectory, considering the performance of experts as a baseline. Performance comparison of experts and novices without visual aid, while different, only differed significantly when it came to the lateral distance when entering the more challenging right bend. Interestingly, while there was no significant difference between the experts and novices with a visual aid, the  $p$ -value  $> 0.95$  for several performance parameters might suggest some equivalency. However, the sample size is too small to conduct a TOST equivalency test. Further testing is required to verify this hypothesis.

The driving behavior differed for novices in both NF and VF conditions. The steering angle differed significantly in the entry on the left bend (entry and exit). Moreover, when comparing the behavior of experts to novices with aid, while no significant difference was found, a  $p$ -value  $> 0.95$  was found for the steering angle in the more challenging right bend on the exit phase, which suggests that the steering behavior might be similar. However, more tests have to be done to validate this hypothesis.

The eye behavior for the novices changed significantly between novices without visual aid and novices with a visual

aid in both the entry and exit phases in the left bends and in the entry phase in the right bend. This difference was expected since the participants were aided to change their eye behavior to track the tangent point. However, this confirms that the novices followed the visual aid but were looking further away on the road when no visual aid was provided. In the case of the visual aid, these values were closer to the expert values. This contrasts with some of the literature regarding novice drivers looking much closer to the road than experts [22]. However, these studies were done on beginner drivers on actual roads and on cars only (not on motorcycles). The distribution of gaze data also changed significantly in novices in NF vs. VF conditions, the focus shifted more to the inside lane of the curve and near the tangent point.

## V. CONCLUSIONS

In this paper, we have investigated the impact of visual aid on driving performance, steering behavior, and gaze behavior. A VR environment was developed and connected to a physical platform while using an HMD. Using this setup, a driving experiment to investigate the impact of a visual aid on novice riders was done, with a group of experts serving as a baseline. The results of this experiment show some differences when driving on a more challenging curve between novices in both conditions with a tendency to get closer to experts' behavior when the visual-aid was provided. While the eye behavior of aided novices was closer to the experts in the hard cases, there is still some difference because the experts do not follow the tangent point model all the time. The current study was an exploratory work and it has some limitations. First, while some performance metrics were closer to experts, no equivalency test was performed due to the low number of participants. As mentioned, the differences are found on harder, more curved bends, which suggests that we must introduce some difficulty to the driving experience to be able to surpass the skill level of novices and stay in the experts' range to be able to differentiate between them, as it is harder to find differences when the task is easy for everyone. The second Limitation is related to the simulator fidelity. As known, the motorcycle is a very dynamic system, and it relies heavily on the rolling action of the vehicle, which was absent in our setup. This may have led to different steering behavior and possibly different gaze behavior. This suggest using a higher fidelity simulator with rolling action in our future studies. Third, only one participant drives a motorcycle every day on the road with more than two years of experience and can be considered as an actual expert. Also, most novices already have a car driving licence which may have impacted their gaze behavior. In the future, we plan to do a real-world study with experts in order to build a more accurate model of their gaze behavior while driving in bends. We plan also to run a new experiment on a simulator with rolling action for both experts and novices on a larger scale to investigate the differences between actual and simulator behaviors.

## REFERENCES

- [1] ONISR, "La sécurité routière en France: Bilan de l'accidentalité de l'année 2019," ONISR (Observatoire National Interministériel de la Sécurité Routière), Tech. Rep., 2019.
- [2] T.-C. Lin, S. Ji, C. E. Dickerson, and D. Battersby, "Coordinated control architecture for motion management in ADAS systems," *IEEE/CAA J. Autom. Sinica*, vol. 5, no. 2, pp. 432–444, Mar. 2018, doi: 10.1109/jas.2017.7510814.
- [3] Farroni, Flavio, Timpone, Francesco, Russo Spena, Maria. (2015). Virtual Testing of Advanced Driving Assistance Systems. *International Journal of Mechanics*. 9. 300-308.
- [4] H. Ueno, M. Kaneda, and M. Tsukino, "Development of drowsiness detection system," presented at the VNIS'94 - 1994 Vehicle Navigation and Information Systems Conference.
- [5] L. M. Bergasa and J. Nuevo, "Real-time system for monitoring driver vigilance," presented at the Proceedings of the IEEE International Symposium on Industrial Electronics, 2005.
- [6] E. Lehtonen, O. Lappi, H. Kotkanen, and H. Summala, "Look-ahead fixations in curve driving," *Ergonomics*, vol. 56, no. 1, pp. 34–44, Nov. 2012.
- [7] B. W. Tatler, M. M. Hayhoe, M. F. Land, and D. H. Ballard, "Eye guidance in natural vision: Reinterpreting salience," *Journal of Vision*, vol. 11, no. 5, pp. 5–5, May 2011.
- [8] D. H. Ballard, M. M. Hayhoe, and J. B. Pelz, "Memory Representations in Natural Tasks," *Journal of Cognitive Neuroscience*, vol. 7, no. 1, pp. 66–80, Jan. 1995.
- [9] N. Mennie, M. Hayhoe, and B. Sullivan, "Look-ahead fixations: anticipatory eye movements in natural tasks," *Exp Brain Res*, vol. 179, no. 3, pp. 427–442, Dec. 2006.
- [10] A. L. Yarbus, "Eye Movements During Perception of Complex Objects," in *Eye Movements and Vision*, Springer US, 1967, pp. 171–211.
- [11] M. Shepherd, J. M. Findlay, and R. J. Hockey, "The Relationship between Eye Movements and Spatial Attention," *The Quarterly Journal of Experimental Psychology Section A*, vol. 38, no. 3, pp. 475–491, Aug. 1986.
- [12] J. Theeuwes, A. Belopolsky, and C. N. L. Olivers, "Interactions between working memory, attention and eye movements," *Acta Psychologica*, vol. 132, no. 2, pp. 106–114, Oct. 2009.
- [13] M. K. Eckstein, B. Guerra-Carrillo, A. T. Miller Singley, and S. A. Bunge, "Beyond eye gaze: What else can eyetracking reveal about cognition and cognitive development?," *Developmental Cognitive Neuroscience*, vol. 25, pp. 69–91, Jun. 2017.
- [14] E. Crundall, D. Crundall, and A. W. Stedmon, "Negotiating Left-Hand and Right-Hand Bends: A Motorcycle Simulator Study to Investigate Experiential and Behaviour Differences Across Rider Groups," *PLoS ONE*, vol. 7, no. 1, p. e29978, Jan. 2012.
- [15] <https://moto-securite.fr/comprendre-trajectoire/>
- [16] R. Lobjois, V. Dagonneau, and B. Isableu, "The contribution of visual and proprioceptive information to the perception of leaning in a dynamic motorcycle simulator," *Ergonomics*, vol. 59, no. 11, pp. 1428–1441, Feb. 2016.
- [17] : D. Crundall, A. W. Stedmon, E. Crundall, and R. Saikayast, "The role of experience and advanced training on performance in a motorcycle simulator," *Accident Analysis and Prevention*, vol. 73, pp. 81–90, Dec. 2014.
- [18] R. Lobjois and F. Mars, "Effects of motorcycle simulator configurations on steering control and gaze behavior in bends," *Journal of Experimental Psychology: Applied*, vol. 26, no. 1, pp. 108–123, Mar. 2020.
- [19] "Correction: Driver Gaze Behavior Is Different in Normal Curve Driving and when Looking at the Tangent Point," *PLoS ONE*, vol. 10, no. 9, p. e0139410, Sep. 2015.
- [20] M. F. Land and D. N. Lee, "Where we look when we steer," *Nature*, vol. 369, no. 6483, pp. 742–744, Jun. 1994.
- [21] O. Lappi, "Future path and tangent point models in the visual control of locomotion in curve driving," *Journal of Vision*, vol. 14, no. 12, Association for Research in Vision and Ophthalmology (ARVO), pp. 21–21, Oct. 21, 2014.
- [22] Mourant, R. R., and Rockwell, T. H., 'Strategies of visual search by novice and experienced drivers. *Human Factors*', Vol. 14(4), pp. 325-335, 1972.