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# Objective and subjective evaluation of motorcycle helmet visors based on ECE 22.05 regulations

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## Abstract

With the growing demand for helmet mounted displays on motorcycle helmets, it is essential not to compromise the peripheral vision of the motorcyclist. The relevant European standard of motorcycle helmet visors ECE 22-05, equivalent to the DOT standard FMVSS 218, states that the visor should permit peripheral vision horizontally through an arc of 105° from the helmet midline and vertically through an arc of 52°, which is located 7° upwards and 45° downward from the eyes. Consequently, this study compares a 3D environment to a human testing environment and an controlled testing environment using standard headforms to create an objective method to verify the correct field of view of motorcycle helmets. Firstly, the 3D environment is developed in Solidworks and provides a simulation set up that validates the necessary field of view in reference to the ECE 22-05. This environment is matched up to the testing environment with test subjects that are familiar with the use of a motorcycle helmet. The fields of view were determined by 12 indication points for 9 different motorcycle helmet models. The downwards tilt of the helmet of each test subject was individually determined. Each participant was additionally tested with a control helmet. The control helmet was also 3D scanned for use in the 3D environment. This provides a reference for the tilt of the helmet in the other two objective evaluation methods. With an average downwards angle of 21.1 degrees down, the control helmet has a success rate of 66.7% in the testing environment with the test subjects, although a number of external factors influence the determination of the field of view of the test subjects. Lastly, a field of view was generated by means of a human headform model into which a Ricoh Theta 360 camera was inserted. This results in an objective field of view for the control helmet. The synthesized downwards angle was implemented in the 3D environment to generate a 3D render of the field of view with the 3D scan of the control helmet. The render shows a similar field of view to the field of view generated by the Ricoh Theta 360 camera, resulting in a confirmation of the validity of the 3D model. Combining these three methods of testing, guarantees an objective evaluation of motorcycle helmet visors.

**Keywords:** Certified Motorcycle Helmet - Field of View - Objective Verification Tool

# 1 Introduction

The perception of the road conditions is critical to motorcycle riders. *A helmet limits the rider's peripheral vision, which is crucial regarding the perception of speed* [1]. The rider moves their head and eyes away from the road to monitor the dashboard. This causes a higher risk of miscalculating road events that can lead to accidents [2]. Optical see-through augmented reality (OST-AR), by means of a helmet mounted display (HMD) displays the vital information regarding the dashboard within the field of view of the motorcycle rider. However, the regulations concerning the limited field of view must be met. These regulations are conforming to the ECE 22-05 [3]. *Developers want to ensure the correct and objective use of these regulations while developing new motorcycle helmets.* However, there is not yet an objective method available that is both easy to use and accessible to all developers.
There are a number of studies regarding HMD's specifically for aviation-based helmets. While these helmets have the same requirements regarding the field of view, they do not have similar visors. [4] [5] These studies, therefore, cannot be used in the development of motorcycle helmets, more specifically, the verification of the requirements regarding the field of view of a motorcycle helmet. Although, *these studies can be used as a reference to methodology.*
The aim of this study is to create *an objective method of verification for motorcycle helmets both in simulation software and in human testing*. In order for this method to be substantiated, a number of tests were performed. *A Solidworks 3D environment* was created containing an accurate human head [3] and a test set up. This set up was replicated in a usability lab to be used during *tests with subjects that are familiar to the use of a motorcycle helmet*. These tests resulted in a number of fields of view and these were compared to the simulated field of view from the 3D environment. With the outcome of this study, we strive to generate an objective 3D environment that can be utilized by manufacturers of motorcycle helmets for the verification of the field of view of new models.

# 2 Materials and methods

Three methods of simulating the field of view of motorcycle helmets were applied to a standardized helmet. The standardized helmet is a HJC RPHA Max Evo, Size L and is certified *in reference to the ECE 22.05 specifications*.

**Method 1**

This method is applied *in a physical usability lab with test subjects*. The test is performed on 6 different test subjects with 9 different helmet models, one being the standardized helmet. The test subjects are *frequent motorcycle users* and familiar to wearing a motorcycle helmet. In this test, the test subjects are positioned in front of *a two-piece grid*. The grid is marked in the middle (Figure 1). This is the focal point of the test subject. The position of the subjects is determined by two strings that are equidistant to the grid. While positioning the subject, both strings are tensioned, making the test subject stand in the correct position. This means a 1m offset perpendicular to both grids. These strings are not directly attached to the grid, because of the changes in height per test subject. By means of two rods attached to the grid (Figure 2), the string height can be adjusted according to the eye height of the test subject. The subject is focusing on the center mark, meanwhile a green dot that is attached to a rod is slowly being moved into the field of view. Once the dot is spotted, it is placed onto the grid resulting in a border point of the perceived field of view. With the use of 12 key points, the field of view is determined. Each test subject performs this test with two helmets, one being the

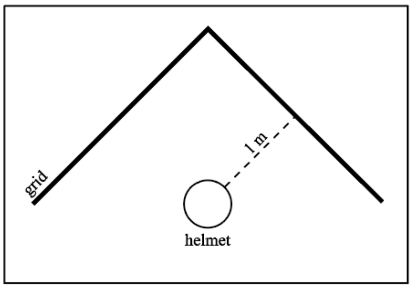


*Figure 1*

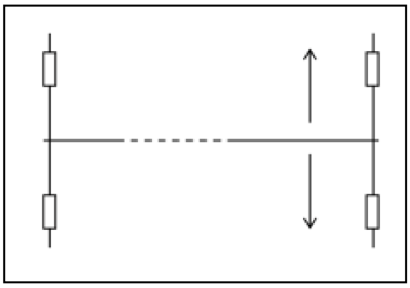

*Figure 2*

standardized helmet. The field of view is captured by a Ricoh Theta 360 camera for later comparison to the other two methods.

**Subtest**
During the subtest, that is performed in a usability lab as well, the subjects stand in a transversal position (Figure 3). The subjects are photographed with the helmet on in a neutral position. Afterwards, the downwards angle of the helmet is processed.

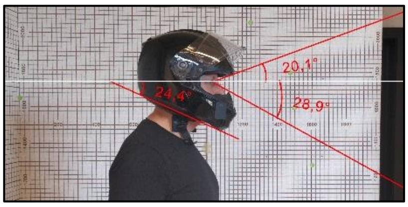


*Figure 3*

**Method 2**
In the second method a 3D modeling program, *Solidworks*, has been used to simulate the users view. A 3D scan of the helmet is positioned on a verified 3D head model [3]. The helmet and head are placed in *a 3D modelled environment*. In the environment the grids are simulated. This position (Figure 4) has been recreated based on method 1. However, the tilt of the helmet affects the field of view. In order to verify the correct downwards angle of the head, a subtest (see subtest) was executed.

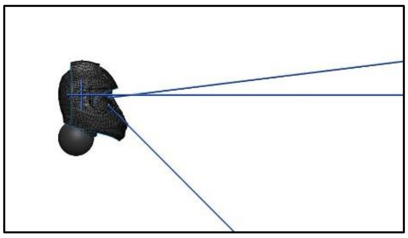

*Figure 4*

**Method 3**
Lastly, the field of view of the standardized helmet is determined by a Ricoh Theta 360 camera. Inside a verified human head model, the 360 camera is attached in reference to the ECE 22.05 standards (Figure 5). The standardized helmet is placed upon the head model. Subsequently, the verified human head model is mounted on a tripod and placed in front of the two-piece grid. The position is measured according to the strings and the Ricoh Theta 360 camera captures a field of view.

*Figure 5*

Afterwards, the fields of view are processed. These different methods of capturing the field of view are compared, in order to proof the authenticity of the verification tool in a 3D setting.

## 3 Results

***Method 1 – Usability Lab Test:***
As shown in Table 1, two out of six test subjects did not pass the test regarding the minimal vertical field of view with the standardized helmet. In the test with their own helmets, again two subjects did not pass the test. However, in this test, the subjects failing the test are different subjects than in the first test using the standardized helmet. The table also shows the different angles of the helmet when the test subjects put it on. These angles, regarding the standardized helmet, are 21,15 ± 4,11 degrees.

| *Test subject name* | *Nr. Test subject* | *Standard helmet* | | *Space between FoV standard helmet and FoV specification* | *Own Helmet* | | *Quality mark* |
|---|---|---|---|---|---|---|---|
| | | *Passed test?* | *Position (degrees)* | *(in decimeters)* | *Passed test?* | *Position (degrees)* | |
| Frank | 1 | y | 17 | 0 | n | 22,2 | ECE 22.05 |
| Ils | 2 | n | 17 | -1,5 | y | 17,6 | FMV88 218 |
| Kris | 3 | n | 18,6 | -1 | y | 18,1 | ECE 22.05 |
| Kris | 4 | y | 23,4 | 1,75 | y | 21,2 | ECE 22.05 |
| Sylvie | 5 | y | 26,3 | 1,25 | y | 28,3 | ECE 22.05 |
| Matthias | 6 | y | 24,6 | 0,5 | n | 24,1 | None |
| Kris 2 | 7 | | | | y | 21,6 | ECE 22.05 |
| Matthias 2 | 8 | | | | y | 30,8 | ECE 22.05 |
| Ricoh Theta 360° | | y | | 2,5 | | | |

*Table 1 - results method 1 - vertical field of view*

| Test subject name | Nr. Test subject | Standard helmet | | Space between FoV standard helmet and FoV specification | Own Helmet | | Quality mark |
|---|---|---|---|---|---|---|---|
| | | Passed test? | Position (degrees) | (in decimeters) | Passed test? | Position (degrees) | |
| Frank | 1 | n | 17 | 0 | n | 22,2 | ECE 22.05 |
| Ils | 2 | y | 17 | -1,5 | n | 17,6 | FMV88 218 |
| Kris | 3 | n | 18,6 | -1 | n | 18,1 | ECE 22.05 |
| Kris | 4 | n | 23,4 | 1,75 | y | 21,2 | ECE 22.05 |
| Sylvie | 5 | n | 26,3 | 1,25 | n | 28,3 | ECE 22.05 |
| Matthias | 6 | n | 24,6 | 0,5 | n | 24,1 | None |
| Kris 2 | 7 | | | | y | 21,6 | ECE 22.05 |
| Matthias 2 | 8 | | | | n | 30,8 | ECE 22.05 |
| Ricoh Theta 360° | | y | | 2,5 | | | |

*Table 2 - results method 1 - horizontal field of view*

In the horizontal view only one person passes the test with the standard helmet. This is an unexpected result, considering the standard helmets. For the test with their own helmet, Kris (test subject 4,7) passes twice with his own helmets (two).

The resulting field of views were combined into one heatmap (Figure 6) where all field of views are layered on top of each other and levelled with one eye height. The thinner more opaque line is the most saturated edge of all the field of views combined. The wider less opaque band shows the variation of the edges of the fields of view. The yellow colored center cross is the safe zone, which is the minimal field of view in reference to ECE - 22.05 standards.

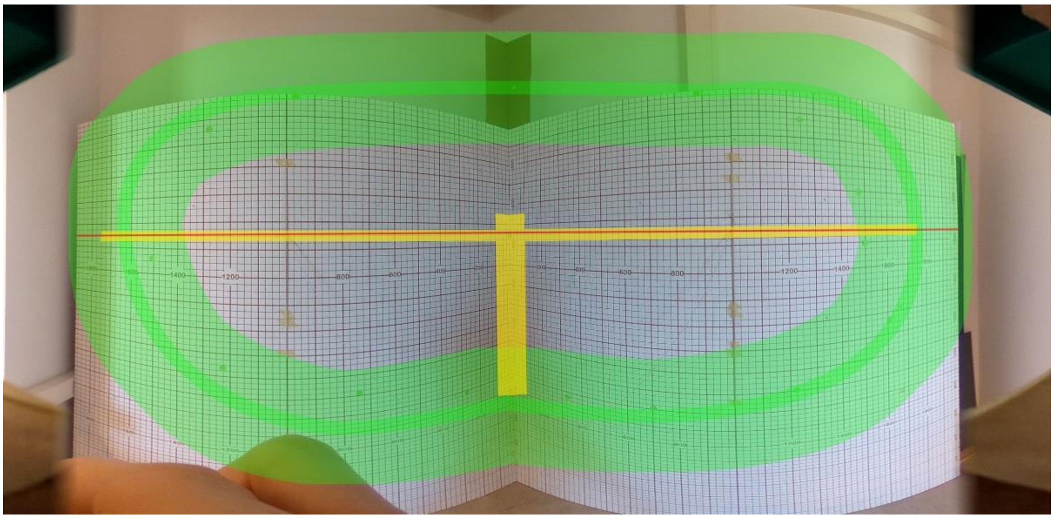

*Figure 6 – heatmap field of view – taken with Ricoh Theta 360*

***Method 2 – 3D environment:***
A 3D model of the standardized helmet is scanned in and brought into Solidworks 2019 (Figure 7). The placement of the helmet strongly influences the resulting field of view. [6] Misplacement could result in a render that is not representative of the actual field of view of human test subjects. To determine the bottom angle of the helmet in this 3D environment, we refer back to the subtest. During this test, we gathered an average bottom angle of 21,15 ± 4,11 degrees. We implemented these measurements into a 3D model. The render itself is captured with a 360-degree camera function in visualize (Solidworks).

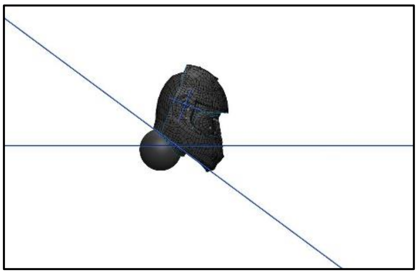

*Figure 7 – bottom angle 3D model*

***Method 3 – Ricoh Theta 360-degree Camera:***
This method shows the field of view of an inhuman test subject that would have a perfect spherical vision.[7] The resulting field of view, generated with the use of a Ricoh Theta 360 camera, shows a similar image (Figure 8) to the generated heatmap of method 2. The one defining difference is the width of the image. This refers to the capabilities of the peripheral view of the test subjects, which will be discussed later in this study.

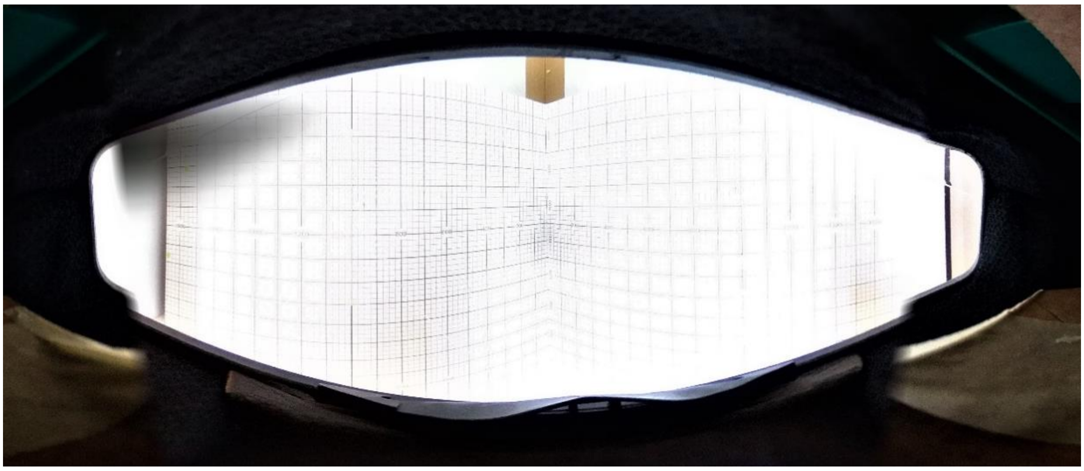

*Figure 8 – generated field of view – Ricoh Theta 360 Camera*

***Comparison of method 2 and 3***

The heatmap of method 1 is projected onto the field of view generated by the 3D environment (Figure 9) and the Ricoh Theta 360 image (Figure 10). The results of both images are similar. Both the safe zones are indicated and the fields of view overlap.

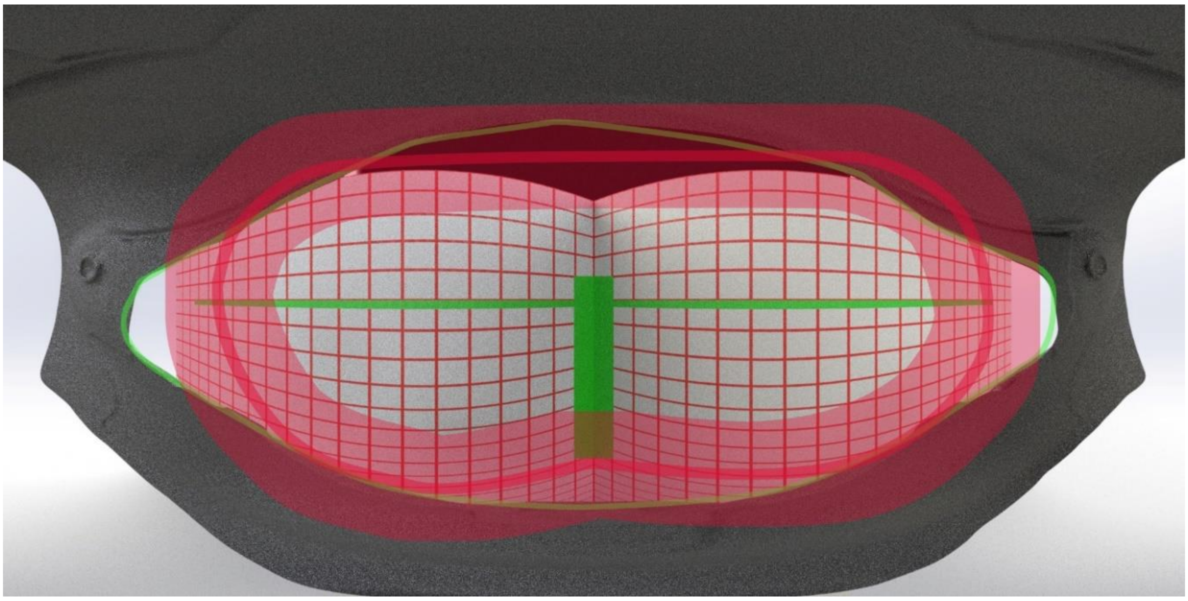

*Figure 9 – 3D environment – field of view*

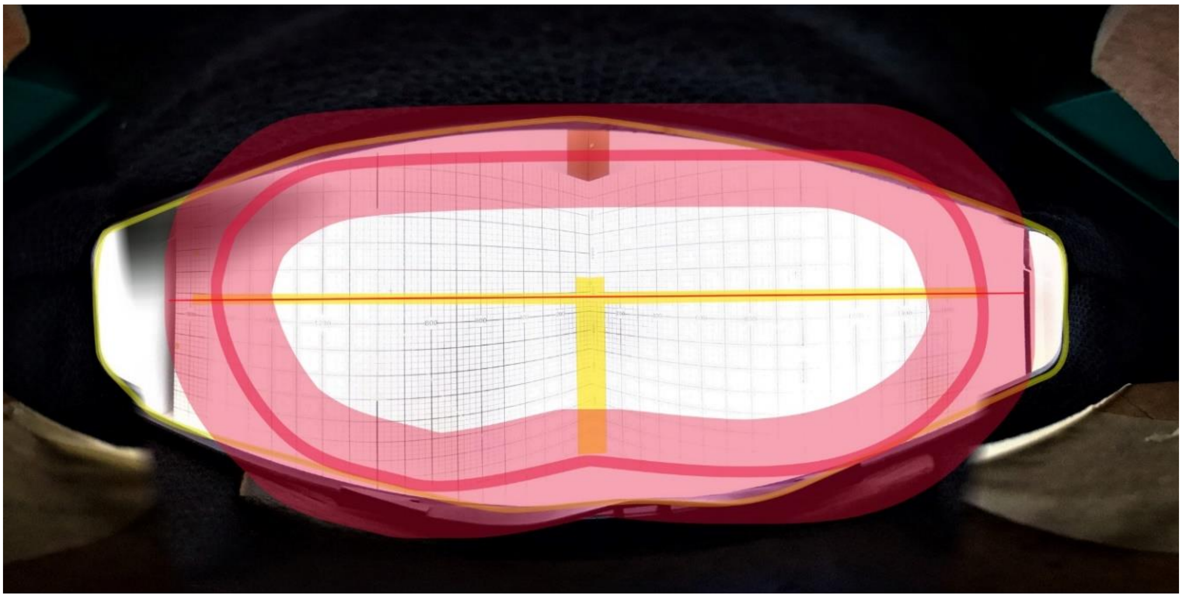

*Figure 10 – Ricoh Theta 360 – field of view*

## 4 Discussion and conclusion

***The subjectivity of method 1***

Only one of six subjects passed the test relating to the lateral field of view. This can be accounted for in two different aspects. Firstly, these results are affected by the peripheral view [8] of the test subjects. During the test, *five out of six subjects* did not succeed in seeing the edge of the lateral field of view. When asked about it, they did not feel that the helmet was blocking their field of view, however it was their respective field of view [8] that was not as wide as the ECE -22.05 reference prescribed. During the test the subjects are asked to focus on one fixed dot at eye height. We do this to refrain the subject from moving their head during the test. But by focusing on the dot, the eyes could not move. The image of the Ricoh Theta 360-degree Camera visualizes the potential field of view without any peripheral hinderance except for the helmet. This image results in a wider field of view, that corresponds with the ECE - 22.05 reference. Secondly, there is a problem with perception. [8] We use people as test subjects and they each have a different manner of perceiving their surroundings. [8] Health, age, lifestyle, attention span and reflexes can influence the perception of the moving targets during the tests. Our resources are not complete enough to rule out certain anatomical and external factors that might influence the results.

***More test subjects during method 1***

We tested six subjects in total. This is a relatively low number of test subjects during research. However, adding to the pool of test subjects could potentially raise more subjectivity. As mentioned before, the resources are not complete enough to filter out the external factors that might influence the method in itself. Adding more possibilities for these external factors might influence the objectivity of the paper.

***Objectivity of the 3D environment and the Ricoh Theta 360 Camera***

Both the 3D environment and the camera images are based on the synthesized angle that we gathered from the first test. This angle is based off of the side images of the test subjects. We tested six subjects. The variation in the bottom angle was limited. This synthesized angle was used to both angle the helmet in the 3D environment as well as the helmet on the rigged head with the Ricoh Theta 360 Camera. This angle is dependent on the objectivity of the test subjects. We previously established that the use of more test subjects based on the field of view could potentially have a negative effect on the objectivity of this study, however it is certain that increasing the amount of side images will further create a more objective base [9] for the synthesized side angle that was used to position the helmets.

Aside from that aspect, both the Ricoh image and 3D render presented the same field of view, and created an objective method of predicting the field of view with different helmets. We can state this because the angle in itself was the same in both cases and the imagery is a match.

***Conclusion – objective tool for the verification of the field of view***

In this study, three different testing methods have been compared and converged in one evaluation. This way of evaluating helmets is accessible to any developer, designer or researcher for further use. The goal was to create an objective evaluation method that generates a singular definitive image that either passes or fails the helmet that is being tested, based on the field of view. For this to happen, we created a neutral testing environment and based on multiple different methods of testing, we generated an analog and a digital evaluation. The analog evaluation, using a 360 camera and a rigged head is more time consuming. The setup for testing the field of view of potential helmets will need the exact same testing situation as shown in method 3. For the digital evaluation, a simple CAD file is sufficient. The test setup in itself is already made and accessible, in order to provide an objective evaluation setup. The human testing in itself is not necessary for generating a field of view, however the side angles are vital for the positioning of the helmets, since there are no guidelines regarding the exact positioning of the helmet on the head.

## 5 Acknowledgements

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