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# EYE MOVEMENTS WHILE CYCLING IN GTA V

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## ABSTRACT

*A common limitation in human factors research is that vehicle simulators often lack perceptual fidelity. Video games, on the other hand, are becoming increasingly realistic and may be a promising tool for simulator-based human factors research. In this work, we explored whether an off-the-shelf video game is suitable for research purposes. We used Grand Theft Auto (GTA) V combined with a Smart Eye DR120 eye tracker to measure eye movements of participants cycling in hazardous traffic situations. Twenty-seven participants encountered various situations that are representative of urban cycling, such as intersection crossings, a car leaving a parking spot in front of the cyclist, and the opening of a car door in front of the cyclist. Data of participants' gaze on the computer monitor as recorded by the eye tracker were translated into 3D coordinates in the virtual world, as well as into semantic information regarding the objects that the participant was focusing on. We conclude that GTA V allows for the collection of useful data for human factors research.*

## KEYWORDS

Simulation, bicycle, driving, hazard perception, gaming.

## 1. INTRODUCTION

The Netherlands hosts more bicycles (22 million) than residents (17 million) [31]. Thirty-six percent of the Dutch residents use their bicycle on a daily basis [7]. The popularity of cycling is reflected in accident statistics: while the Netherlands has the second lowest fatality rate per million inhabitants of the EU member states, the share of cyclist fatalities is higher (25%) than the average of the member states (8%) [8]. It is important to understand the behaviour of cyclists in traffic, and simulators can provide a safe and controlled environment for that. A small number of simulators for bicycle research exist [13], [15], [18], [19], [28], [32–34], [37]. However, many of these simulators do not provide a high level of perceptual realism.

The visual fidelity of video games has risen steadily in the past decades. The advanced capabilities of modern video games and their high level of realism have triggered interest in their potential as research platforms (e.g., Need for Speed [14] and rFactor [36]).

In this work, we opted for Grand Theft Auto (GTA) V [25]. GTA V offers a realistic visual environment with a great variety of vehicles, pedestrians, and other road users, and has already been used for research purposes, for example, for automated semantic labelling, as needed for machine learning in automated driving [9], [16], [17], [21–24].

A video game needs to be modifiable to perform human factors research. GTA V can be modified using Script Hook V [1] in C++, .NET (C#, F#, Visual Basic) [4], and Lua [10]. Furthermore, the GTA V community offers a large number of mods and plugins [11].

Simulators are often combined with eye trackers to understand the user's visual behaviour, such as aspects of hazard perception [5] and cognitive workload [20]. However, in most cases, the eye tracker is only used to provide the gaze coordinates on the screen. Ray casting can be applied to convert eye-tracking data into coordinates in the virtual world and object mapping (e.g., [3], [6]). This paper aims to demonstrate the feasibility of combining an eye tracker with GTA V to investigate cyclists' behaviour in hazardous situations.

## 2. METHOD

### 2.1. Apparatus

The virtual bicycle was controlled by the participants via a game controller. GTA V was run on a gaming PC, using a maximum setting of the quality of graphics.

We used the Smart Eye DR120, a remote 3D eye tracker with a 24-inch HD screen. The eye tracking sampling rate was 120 Hz [30]. The purpose of the eye tracker was to record where a participant looked at on the screen. To integrate information from the eye tracker in GTA V, we used the UDP logging protocol.

The "world intersection" feature of the eye tracker [29] was used to determine where the participant was looking at on the screen and in the GTA V world. The coordinates received by the eye tracker are relative to the screen size and fall within the range (0, 1). To convert the screen coordinates into world coordinates, we used a camera transformation matrix, which was read from GTA V memory by utilising signature scanning [2]. This transformation matrix was then applied in reverse to the screen coordinates to retrieve the direction vector of the participant's gaze. With this vector, we ray cast [12] from the camera in the direction of the gaze to retrieve whether the participant was looking at an actor. We logged frame numbers from the eye tracker for the synchronisation with data from GTA V.

## 2.2. Scenario

A route suitable for cycling and with several intersections was chosen from the GTA V environment.

Participants cycled along an S-shaped route (Figure 1). The route consisted of 12 traffic situations in an urban environment without cycling lanes. Most of the traffic situations were ordinary ones, such as intersection crossings. Some hazardous situations were also included, such as the opening of a car door right in front of the moving cyclist. In the ordinary situations, the participant would not need to take immediate action but is likely to attend to the event. In the hazardous situations, a reaction of the participant would be necessary to avoid an accident. Specifically, the following traffic situations were included in the scenario:

*S1: Car from the left*. A car drives past from the left side; the cyclist is going straight ahead. There is no need for the cyclist to brake (Figure 2).

*S2: Car leaves parking space*. A car unexpectedly leaves its parking space in front of the cyclist (Figure 3). An immediate reaction of the cyclist is required.

*S3: Intersection; a bus passes*. A bus approaches from the right. There is no need for the cyclist to brake, since the bus is quite early.

*S4: Motorcycle passes by from the opposite direction*. The cyclist is instructed to turn left, but a motorcycle drives past from the opposite direction. The cyclist has to wait for the motorcycle to pass by.

*S5: Pedestrian crosses over*. The cyclist will take a right turn on the next intersection but has first to stop for a pedestrian crossing the street from the left.

*S6: Intersection with traffic lights*. The cyclist goes straight ahead but has to wait for a red light. Meanwhile, a car and a bus cross the intersection.

*S7: Unexpected opening of a car door*. Two cars are parked. The first car starts driving as a distraction. When the cyclist reaches the second car, the car door opens. An immediate reaction of the cyclist is required.

*S8: Intersection with traffic lights*. The cyclist will turn right at the next intersection but has first to wait for a red light. Meanwhile, a car passes by from the left.

*S9: Intersection with traffic lights*. The cyclist goes straight ahead but has to wait for a red light. Meanwhile, a car crosses the intersection from the right, with high speed.

*S10: Intersection*. The cyclist will take a left turn at the next intersection but has first to wait for a car from the left and a motorcycle from the right.

*S11: Yellow traffic light*. When the cyclist is close to the traffic light, the traffic light turns yellow and red.

*S12: Police chase*. As the cyclist reaches the traffic light, there is a high-speed police chase on the road the cyclist is about to enter.


**Figure 1** Scenario route in the GTA V world.

A video showing the scenario with the 12 situations can be found in the supplementary material.

The traffic in the scenarios was triggered by the participant's actions. When the participant entered a trigger (i.e., a circle with a certain radius), a piece of code was executed, instructing an actor (i.e., road user) to perform a specific action. For example, when the participant entered a trigger circle, a car started driving. Traffic lights were also controlled by triggers.

**Figure 2** Situation 1 (Car from the left). A car drives past from the left side; the cyclist is going straight ahead. In this visualization, the cyclist is marked with purple circles. The red and green circles are triggers. A trigger is red by default and turns green when the cyclist enters it. The small square marker represents the participant's point of visual attention in the virtual world.

**Figure 3** Situation 2 (Car leaves parking space). A car leaves its parking space in front of the cyclist. Circle annotations as in Figure 2.

## 2.3. Implementation

We chose C# to modify GTA V, due to the safe nature of the language and the large number of code examples available. We used the Community Script Hook V .NET, a .NET wrapper for Script Hook V. Script Hook V was implemented using a detour [35] for DirectX (dinput8.dll) to read and modify GTA V. The mod was programmed in the 'tick' function of GTA V. This function is called at each frame in the main GTA V thread, and only in this thread the modified source is loaded.

We logged the following data at 50 Hz: position, heading, and speed of the participant's bicycle, and timeframe. The source code of the implementation is available in the supplementary material.

## 2.4. Procedure

Before the experiment started, the participants completed a consent form and demographic data, as well as questions about gaming and cycling experience.

Next, the participants received an instruction form and were told to ride the bicycle during the experiment as they would normally do in real life and to obey all traffic rules. Pre-recorded voice messages in English and textual message at the bottom of the screen in Dutch instructed the participants where to go on intersections. All participants completed the same route twice.

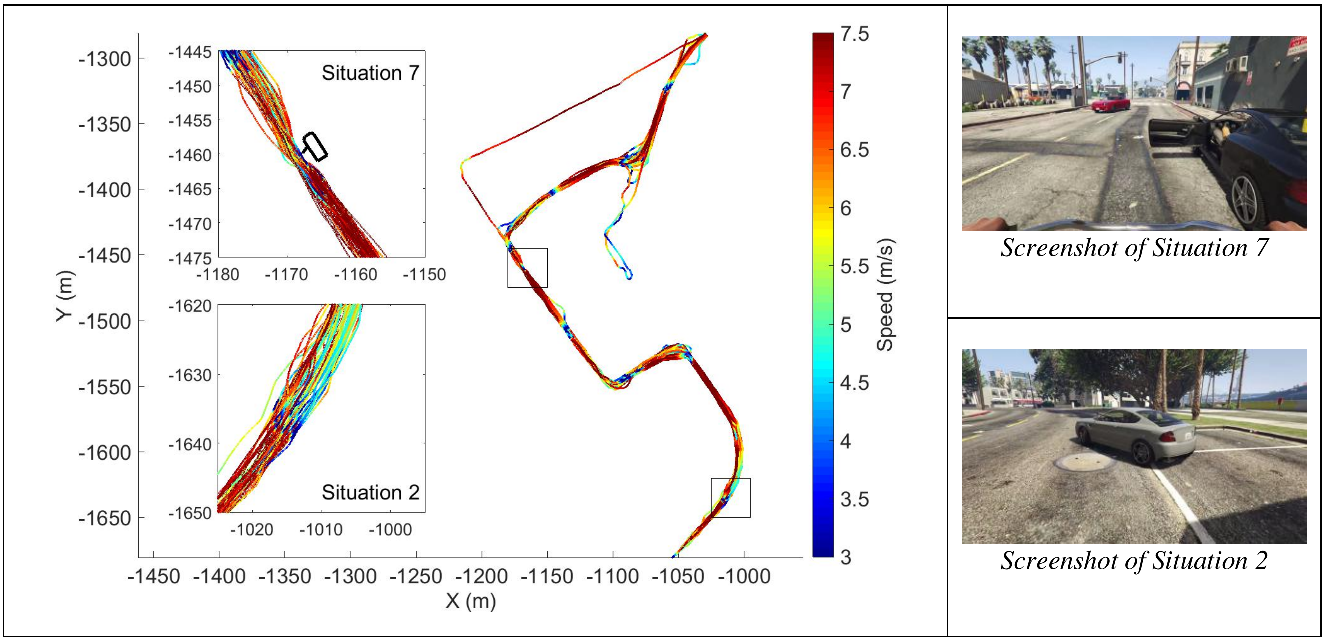


**Figure 4** Top view of the driven path of all participants and screenshots of Situations 7 and 2. The coordinates are in metres. The colour coding indicates the participants' speed. In the inset of Situation 7, the contour of the car with opening door is depicted.

## 3. RESULTS

Twenty-seven participants (21 males) took part in the study. Their mean age was 22 years old (*SD* = 1.93). Twenty-three (85%) participants had gaming experience, and 16 (59%) reported having experience in playing GTA V.

### 3.1. Driven path

Figure 4 shows the driven path of all participants (i.e., 27 participants x 2 runs). It can be seen that a small number of participants did not adhere to the route instructions. It can also be seen that the participants slowed down and evaded the opening car door (Situation 7, top inset) and the car leaving the parking spot (Situation 2, bottom inset).

### 3.2. Eye movements

The gaze coordinates from the eye tracker are integrated into the GTA V environment in real time, and thus it is possible to measure which objects a participant is looking at. Figure 5 depicts a real-time rendering of a participant's gaze at a car at an intersection.

**Figure 5** Real-time render of the participant's gaze at a car at an intersection in the GTA V world. These augmented cues were not visible during the actual experiment.

### 3.3. Driven path with gaze behaviour

Because of the integration of the eye tracker in GTA V, a plot of the driven path with the looking behaviour of a participant can be made. Figure 6 shows a plot of the top view with the objects gazed at by all participants, and Figure 7 shows a plot of the top view of the driven path with the gaze distance for one of the participants.

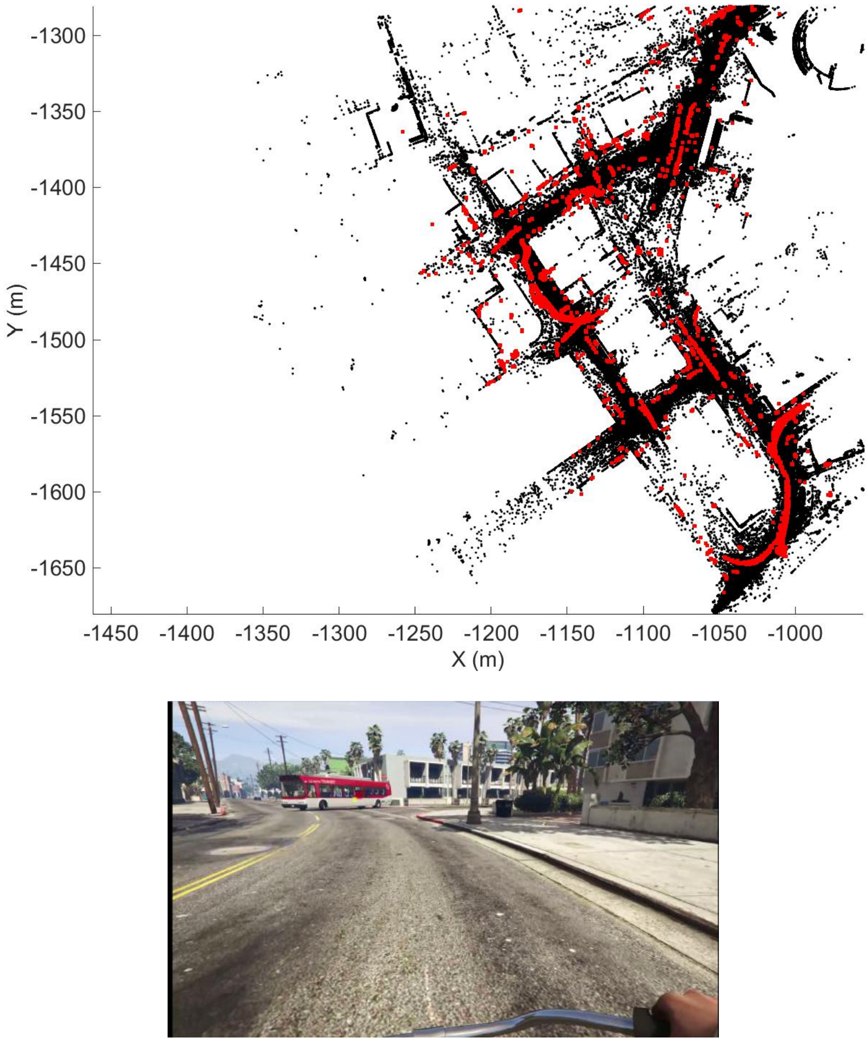


**Figure 6** Top view of the objects gazed at by all participants. The coordinates are in metres. The colour coding indicates whether participants gazed at the road surface (black) or at an object above the road surface (red). That is, the red traces correspond to edges of buildings or other road users (e.g., the passing bus in the case of the bottom screenshot).

## 4. DISCUSSION

In this study, we investigated the potential of collecting data useful for human factors research with the video game GTA V integrated with an eye tracker. We used C# to modify GTA V and to simulate an urban cycling scenario. Furthermore, we used an eye tracker to detect looking patterns of participants by translating their gaze on the computer monitor as recorded by the eye tracker into 3D coordinates in the virtual GTA V world, as well as into semantic information regarding the objects where the participants were gazing at.

Our approach allows linking in real time data on looking patterns from the Smart Eye DR120 eye tracker with GTA V data logs such as the cyclist's heading and speed. Linking these streams in real-time offers the possibility of interactive simulation, as by detecting whether a participant is looking at an actor while moving through the simulated environment, pre-programmed events can be triggered.

Participants controlled the bicycle in GTA V using a game controller. It may be beneficial to develop a setup that links GTA V with a stationary bicycle platform, similar to those of existing cycling simulators. The offered platform may also be an appealing option for car driving research. Future work may focus on the use of the platform for conducting studies on driver safety by applying dynamic scenarios that depend on the participant's gaze. Finally, we note that GTA V only permits modding projects that are single-player, non-commercial, and respect the intellectual property rights of third parties [26], [27].

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## SUPPLEMENTARY MATERIAL

GTA V cycling simulator [Video]. Available at https://www.youtube.com/watch?v=YsYPyUCtlPo

GTA V cycling simulator with gaze data [Video]. Available at https://www.youtube.com/watch?v=yRXrbAKpPT8

GTA V cycling simulator with gaze data and triggers [Video]. Available at https://www.youtube.com/watch?v=6DZVmIkfvHU

GTA V cycling simulator top view with triggers [Video]. Available at https://www.youtube.com/watch?v=POSHpa7_fAw

The Bicycle Experiment Program [Code]. Available at https://github.com/nheisterkamp/bepmod

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