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Design of a teaching unit with a

Virtual Reality Bike Simulator

For students in the school year9.

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Diploma thesis in the context of the CAS Teacher of Transport

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FOREWORD

Cycling is the trend. Whether with or without electric assistance, whether in the countryside or in the city, the bicycle has a future.

As a school instructor in the urban environment of the city of Zurich, I often find myself on the street with children. I am pleased about the increase in bicycle traffic. At the same time, I notice that many cyclists do not obey the traffic rules. Are you not aware of the dangers? Do you consider the risk of a possible measure to be low? Or is it because it has become socially acceptable to still ride fast through the intersection when the light is red? Unfortunately, the accident figures involving cyclists are pointing in the same direction as the sales figures for two-wheelers: upwards. There are many reasons for this.

More repression, i.e. bicycle checks by the police, would help to reduce the number of accidents. In my opinion, however, it would make more sense to work on the attitudes and insights of road users. And that's where the school instruction comes in. We prepare the graduating classes (9th graders) of the city of Zurich in workshops for their role as responsible road users. The focus is on personal responsibility. The motto: "What can I do for my traffic safety?"

Alcohol and distracted driving are important topics here. How can we show these dangers to young people as impressively as possible and thus encourage them to think about their own actions?

The city of Zurich's traffic accident statistics for 2019 prove that prevention pays off: no children were seriously injured or killed! To what extent which measures have contributed to this very good result cannot be determined. However, it shows that all those involved are on the right track and that their work is bearing fruit.

For me, it means that my daily work is worthwhile. This in turn motivates me to reflect on what I do. To bring the knowledge gained through the CAS course "Specialist Teacher for Transport" into my work and to reflect some of it in this work.

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MANAGEMENT SUMMARY

The school instruction of the Zurich City Police trains children from the age of up to 4years16 in safe handling in road traffic. In order to prevent accidents, lessons are taught in a way that is appropriate to the level and has a high practical relevance. The final classes of the regular school level (9th grade), are thereby sensitized to their role as future motorcycle and/or car drivers. In addition to the topics of accident consequences, protective clothing/helmet and seat belts, great emphasis is placed on driving skills, e.g. in connection with alcohol consumption and distraction.

Alcohol consumption and distraction are major causes of traffic accidents. In order to show students, among other things, the causes and consequences in this area as realistically as possible, a bicycle riding simulator was developed from scratch using virtual reality (VR) technology. In the process, the following two questions arose at the outset:

- How can a newly developed VR velo simulator be incorporated into an existing lesson on driving skills related to alcohol consumption as well as distracted driving?

- Can the use of the VR velo simulator generate added value for the students compared to the previous product (scooter driving simulator)?

As a project partner in the development of this VR-Velosimulator I give in this paper the development steps from my point of view. I focus on the integration of the VR-Velosimulator into the existing teaching unit. Thereby I could bring in my concerns and wishes for this teaching unit. These were then taken into account and implemented in the programming of the software.

Fortunately, despite the current adversities (Covid19 pandemic), the VR velo simulator could be used, tested and also evaluated in the status prototype with three graduating classes in real lessons.

From my point of view, the goals I defined were achieved. The students were able to experience the topic of alcohol consumption as well as distraction in road traffic in an impressive way. Since the technology has improved in terms of the experience, it can be assumed that an added value is achieved compared to the previous product.

INTRODUCTION

Learning through experience. This is the motto for traffic accident prevention for the graduating classes (9th grade) of the city of Zurich. These lessons take place each winter semester at the City of Zurich's traffic training facility in Schwamendingen. The young people, aged 15 to years16, are about to graduate from school. It is therefore the last opportunity for us school instructors to make the students aware of the dangers in road traffic. I always look forward to these training sessions because the lessons are structured in an action and practice-oriented way and trigger emotions in students and make them think.

Together with a work colleague, I am responsible for this double lesson. We organize the simulators, create the presentations, etc., so that all school instructors of the city police can teach their classes with these tools. When thinking about whether we are up to date with the topics and content, the following questions arose: Are we teaching the young people the right content that they will encounter in road traffic now or in the near future? Are the accidents and dangers that are also statistically frequent in this age segment? What does the future hold for mobility in an urban environment? Do we rely on the right media and means? How can we continue to improve?

"For the past ten years, serious personal injuries among PW occupants and motorcyclists have declined sharply. In contrast, **no reduction has been** observed for **cyclists** over the same period." (BFU, Sinus page 2019,16)

In 2017, the Traffic Department of the City of Zurich (DAV) produced **360° videos in virtual reality mode to raise awareness among adult cyclists**. A consequence, respectively a pilot project of this was to use these videos in a teaching sequence of the 6th grade for traffic awareness. The project was scientifically accompanied and evaluated by the ZHAW. It showed that the **students with VR glasses** were **more motivated** than their comparison group (Cordin et al., 2019). A disadvantage was the large logistical and technological effort for "only" two lessons compared to classical teaching. If there was a possibility to install the VR simulators stationary, a future implementation might be possible. Internally, the possibility of a fixed installation in the traffic training facility was considered.

We rent so-called "scooter simulators" from the organization "Am Steuer nie, Unfallprävention im Strassenverkehr" (ASN) for the existing 9th grade lessons. We use these for the topic of driving skills. In late fall 2019, I learned that the ASN plans to produce a **"bike simulator with virtual reality technology"** according to their ideas.

In summary, there is a frequency of accidents with cyclists. A new product for training in this area is being developed at ASN. This VR technology could be installed on our premises for the training of classes9. during the winter months.

This results in the following **learning objectives** for the practical lesson:

Target

Make connections related to driving ability understandable to create insights that bring about a behavioral mindset of fewer ☐ traffic accidents.

Rough target

Students know the effects and dangers of alcohol consumption / distraction and its negative effects in road traffic.

Detailed targets

☐	Know that consumption of even small amounts of alcohol, as well as distraction, can have fatal effects.
☐	Experiencing that alcohol consumption leads to increased reaction time, which has a negative impact on the reaction pathway.
☐	Recognize that the consumption of alcohol negatively alters vision.
☐	Experience the impact a brief distraction can have.
☐	Know that drivers may feel fit after consuming alcohol, but in reality they are not and therefore cannot properly assess the risks.

This thesis was made possible by the cooperation with the organization "Am Steuer Nie" (ASN), which initiated the VR-Velosimulator project and offered me my collaboration. ASN (formerly Fachstelle ASN) was founded in Zurich in 1992. The purpose of the association is to make a significant contribution to the reduction of traffic accidents through prevention measures. In particular, the association offers prevention measures in the area of substance-, fatigue- and distraction-related traffic accidents and supports the promotion of comprehensive alcohol prevention in road traffic in Switzerland. ASN relies on a combination of information, fun and creativity in its prevention efforts. Its employees visit high schools, vocational and secondary schools as well as companies and clubs and enriches its clientele with its diverse offer. ASN owns various simulators, which it uses for action-oriented lessons.

MAIN

THEORETICAL BACKGROUND

LESSON TRAFFIC ACCIDENT PREVENTION CLASS9.

Previous story

This lesson for the regular school class9., as it is then later shown at the bottom of the fact sheet, evolved over the decades.

The original aim was to tackle the problem of so-called "disco accidents", i.e. traffic accidents caused mainly at night on weekends by young drivers. The main focus was on the issue of alcohol consumption in connection with driving a vehicle. In order to counteract this one main cause of accidents, a new practical component was created in the form of an alcohol driving simulator in addition to the theoretical instruction. This was a simulated passenger car cockpit with a screen.

Over the years, the teaching has been adapted to the state of the art. Currently, the topic of driving ability in connection with alcohol consumption is taught with the help of a scooter driving simulator.

Current lesson

The scooter driving simulator is a part of the double lesson "Traffic lessons 9th grade". After a common welcome and introduction in the classroom, the class is divided into three groups. These groups then work on three posts for 20 minutes each and change on the fly. At the end, the class meets in the classroom and is dismissed after about minutes.90

	TopicFocus
Welcome/introduction to	☐ the topic
SchoolroomSensitize	☐ accident hazards/accident statistics

Lot impact simulator	Thoughts on "My contribution to my road safety". (active and passive safety) • Explain procedure post work ☐ Simulation of a rear-end collision • Safety belts/headrest
Lot scooter driving simulator	• Visual representation of physical impact on body with video/poster ☐ Driving ability, alcoholandits effects on the body
Item Accident consequences and	• Show the Impact with Alcohol/sober on driving ability • Reaction distance/braking distance/stopping distance ☐ Pointing out the manifold consequences of a traffic accident, with emphasis on recourse claims
Joint conclusion impact simulator/helmet	- Alcohol and its effect on the body - ReasonsforProtectiveClothingonRoller /Motorcycle show ☐ Difference energy impact with/without helmet Handing out of information material (voluntary)
	• Answering questions/farewells

The following fact sheet "Traffic Lessons 9th Grade" shows an overview of the double lesson. This sensitizes students to their future as car, motorcycle or bicycle drivers on the road. The fact sheet serves as preliminary information for teachers and students.

Stadt Zürich
Stadtpolizei

Verkehrsunterricht
9. Klasse

Mit praktischen Anwendungsbeispielen lernen Schülerinnen und Schüler Eigenverantwortung wahrzunehmen und Kompetenzen im Strassenverkehr zu entwickeln. Sie werden motiviert, an ihre persönliche Sicherheit und die der anderen Verkehrsteilnehmenden zu denken.

Doppellektion mit folgenden Schwerpunkten:

Simulierte Auffahrkollision zum Thema Sicherheitsgurte

Die weitreichenden Folgen von Fahren in alkoholisiertem Zustand werden zusammen besprochen (u.a. Regress, Arbeitsausfall, Busse, etc.)

Alkohol und dessen Auswirkungen beim Fahren (Simulationsfahrt am Computer)

Mit praktischen Beispielen wird die Wirkung von Schutzbekleidung und Helm veranschaulicht

Wo: Verkehrschulungsanlage Aubrugg
Aubruggweg 2, 8050 Zürich, 044 413 78 02

Anfahrt: Ab Bahnhof Oerlikon mit Bus Nr. 61, 62, 94 bis Haltestelle 'Dreispitz', weiter zu Fuss in Richtung Verkehrsschulungsanlage

Red framed: The simulation ride on the computer is to be replaced by the VR velo simulator.

Teaching methods and media used

The teaching sequence is conducted in small groups of 5 to 8 students per instructor. By using the VR velo simulator, the active student is presented with a traffic situation that is as close to reality as possible. This is a kind of game-based learning (anticipatory learning, i.e. learning by anticipating future possible situations). By experiencing dangerous situations as realistically as possible (without risk), it is possible to experiment in a targeted manner. From the resulting results, behavior in the real world can then be inferred again. The view of the active student is transmitted to a large flat screen. In this way, the passive students and the instructor also experience the simulation. The experience of the respective sequence is immediately worked out with the students by means of a teaching discussion and conclusions are drawn from it. Through the moving simulation, the different senses are addressed. The following media are used in the teaching unit:

- For the teaching unit, the new VR velo simulator of ASN is used as the main teaching tool.

- To illustrate to the students the statistically higher risk of young drivers to die as a result of a traffic accident, I used a statistic of the BFU in A3 format. Title: Breath alcohol concentration and relative risk of a fatal road traffic accident by age. (BFU, Status 2019, p. 24)

- As part of the double lesson, the students receive a fold-out flyer with safety tips prepared by the school instruction of the Zurich city police. This contains the most important findings of the entire lesson.

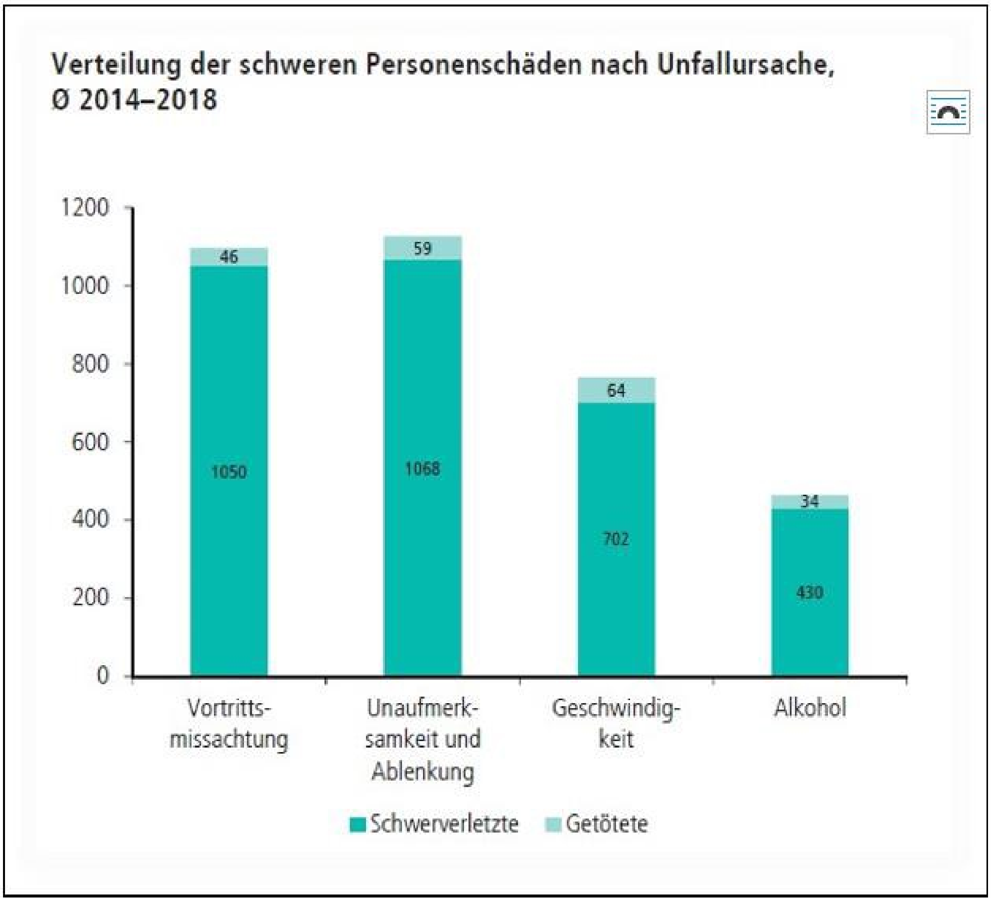
- Numerous posters on the subject of driving skills are visible to young people throughout the area of the traffic training facility. Source BFU; TCS, Zurich city police, etc.

- To reinforce the topic, we provide the students with various brochures, flyers, information material, etc. from numerous providers (ASN, TCS, BFU, etc.) at the end of the lesson.

All media are listed in the appendix.

ACCIDENT HISTORY

"Around 80,000 people are injured in Swiss road traffic every year, and around 200 die. Pedestrians and **cyclists** in built-up areas are particularly at risk. The BFU pays special attention to the behavior of **young new drivers** and the causes of accidents **alcohol** and **speed.** "(BFU, status page 2020,15)



"The most common causes of crashes involving serious injuries or fatalities were **inattention/distracted**2018 driving and failure to yield the right of way. Serious **speeding accidents and serious alcohol accidents** occur less frequently, but are more serious." (AAIB, Sinus page 2019,30)

"In 2018, 431 road users were seriously or fatally injured in alcohol-related accidents in Switzerland." (AAIB, Sinus page 2019,70)

Young adults between the ages of 18 and 24 cause an average of one in 14 serious traffic accidents. They are often the main cause of serious accidents at dusk and in the dark - especially at weekends - and on highways. Men in this age group have significantly more accidents than women, and the proportion of men is significantly higher, especially in skidding and self-inflicted accidents. (BFU, Sinus 2019)

In the city of Zurich, 2015total2019 accidents26'838 and **accidents2603** in which the **main culprit** was **between and18 years24** old occurred in the years to **.** That is 9.7 %. If we take a closer look at the 2603 accidents involving young adults with regard to the main causes of alcohol and distraction, the following figures emerge: In accidents114, the

Main cause "influence of alcohol". That is 4.4 %. In 991 accidents the **main** cause was **"inattention and distraction",** which is approx. %**38,1.** (Traffic accident statistics of the city

Zurich, DAV)

TARGET GROUP ANALYSIS

The target group consists of young people between the ages of 15 and 16. At this age, they are in a phase of transition. On the one hand, they are in the midst of puberty; on the other hand, they are about to graduate from school and thus face groundbreaking decisions regarding their upcoming career choices.

If you put yourself in the current life situation of students, it stands to reason that they may be interested in the topic of traffic safety, but it may not be 1st or 2nd on their current hit list in their personal agenda of most important topics. Similarly, the status of the school instructor, perhaps known since kindergarten, has changed dramatically as school age has increased. Students view the lady or gentleman in the blue uniform with a more critical eye than they did at the beginning of their school career. At this age, students want to be treated as young adults at eye level and demand respect above all else. A few sometimes also tend to be openly provocative toward the teacher.

In order for the lessons to be as successful as possible, it certainly helps if the students have already been taught by the same instructor in the previous years and thus a relationship exists. Furthermore, the instructor is well advised to be aware of the difficult phase in the students' lives and to win them over with professional and social competence.

The practical part of pedestrian and bicycle training, which starts from kindergarten and ends in the The training that took place in the 5th grade has been completed for the young people for a long time. In the sixth, seventh and eighth grade, they work with them in the classroom on traffic sense, right-of-way rules and 3A training (age, intention, attention). Thus, advanced traffic knowledge and a partially developed traffic sense may be assumed. They should be generally familiar with the traffic rules for riding a bicycle. A few students are in possession of the driver's license cat. M (moped) or even cat. F (special category, up to 45 km/h). Traffic experience varies greatly among young people and cannot be generally assumed.

The stage of development at this age varies greatly. At the age of up to 15years16, the young person is in the middle to final phase of puberty. This

Development does not go smoothly for the young people and their environment. Experiences from the classroom confirm, for example, a tendency to overestimate oneself, excessive role behavior (macho behavior) or self-doubt due to a changed appearance. Often, inner vulnerability is met with withdrawal or aggressive behavior.

The reason for this is, among other things, the large anatomical development that takes place simultaneously in the brain, especially in the frontal or frontal lobe. This results in insecurity and confusion in emotional situations: Teenagers react irritably and moodily. Misjudgments and risk-taking are also typical of young people. Since the frontal lobe is primarily responsible for communication, planning actions and suppressing impulses, these specific functions may be impaired during the maturation period. Adolescents evaluate social situations completely differently than adults, especially when it comes to making decisions. Adolescents usually assess dangers less seriously than adults. Their awareness of safety and danger is weaker. Even objectively dangerous behavior is often perceived by them as not risky, but only related to others (this only happens to others, I can react faster or brake better, etc.). This distorted view means that young people are difficult to reach for information campaigns about risks and dangers. Because in their view it only affects others, many are not prepared to change their behavior. Other reasons may include insufficient knowledge (e.g., about speeds, braking distances, effects of alcohol, etc.) and inadequate cognitive skills (too little imagination, logical thinking, etc.). Practical traffic accident prevention and education counteract this and therefore make an important contribution. (Limbourg, page2011, ff6.)

RISK FACTOR ALCOHOL

The following factors lead to an accumulation of traffic accidents among young adults: The use of heavily motorized vehicles, male gender, and limited driving experience. Further, the inappropriate speed, socioeconomic status, alcohol. Alcohol is still a significant influencing factor, but it has decreased due to the ban on alcohol for new drivers. Distraction, especially from cell phones with their various uses, are almost as significant. (Hertach et al., page2019, ff53, BFU).

ALCOHOL CONSUMPTION BY ADOLESCENTS

Alcohol is firmly anchored in Swiss culture. Children learn from an early age that consumption is generally accepted. In adolescence, however, it is not so much the parents but the adolescents of the same age who influence the use of alcohol (and/or possibly other addictive substances as well). The consumption of alcohol in adolescence can serve various purposes: the feeling of being an adult, belonging to a group, reducing fears or inhibitions, enduring boredom or loneliness.

Source: Internet, suchtschweiz.ch

As can be seen clearly on the graph above, male pubescents consume more alcohol than the female gender of the same age. Alcohol is widespread among adolescents. For many adolescents and young adults, "pre-drinking" before going to a club is simply part of the routine. (Internet, suchtschweiz.ch)

LEGAL BASIS FOR THE CONSUMPTION OF ALCOHOL IN ROAD TRAFFIC

Since October,1. drunk driving is no longer normally2016 punishable with a

blood test, but measured with the breath alcohol sample. New, reliable breath alcohol measuring devices determine how many milligrams of alcohol are contained in one liter of breath. With the new measuring method, the unit of measurement changes to mg/l instead of per mille. This halves the values: **0.5 per mille now corresponds to 0.25 mg/l.** The measuring method has thus changed, but not the limit values. The advantages: quick result, painless test and a favorable procedure. With a view to the following table (p. 16) and the physiological effects that occur, it is not surprising that the limit for driving a motor vehicle is mg/l0.25 breath alcohol concentration (or 0.5 per mille blood alcohol concentration). From 0.25 mg/l, one is liable to prosecution in the sense of drunkenness (degree of violation). A qualified alcohol concentration is when the breath alcohol concentration is 0.4 mg/l or more. It is an offense and leads to a warning withdrawal of the driver's license. Since January 1, 2014, new drivers (probationary driver's license holders) have been subject to a complete ban on driving under the influence of alcohol.

From a measurement point of view, the value must be below 0.05 mg/l (0.1 per mille). This regulation is also valid for learner drivers, accompanying persons on learning journeys, professional drivers and driving instructors. When driving a bicycle (motorless vehicle) the same value applies as for motor vehicles (violation from mg/l0.25). (SVG, / 2020TCS, Alcohol and consequences, p2018,.

4 ff.)

PHYSIOLOGICAL EFFECTS OF ALCOHOL

Blood alcohol concentration in per mille (corresponds to breath alcohol concentration)	Alcohol can affect the human organism in the following ways:
0.2 - 0.5 (0.1 -0.25 mg/l)	Attention, visual acuity and hearing performance decrease. Reaction times, as well as the tendency to take risks, increase.
0.5 - 1 (0.25 -0.5 mg/l)	Balance is disturbed, reaction time increases noticeably, night vision and concentration are reduced. Inhibitions are reduced, overestimation of driving ability increases.
1 - 2 (0.5 -1 mg/l)	Speech disorders, confusion, orientation difficulties, tunnel vision.
About 2 (Above mg/l1)	Memory lapses, impaired consciousness, loss of motor coordination. Risk of acute alcohol intoxication with paralysis and respiratory arrest.

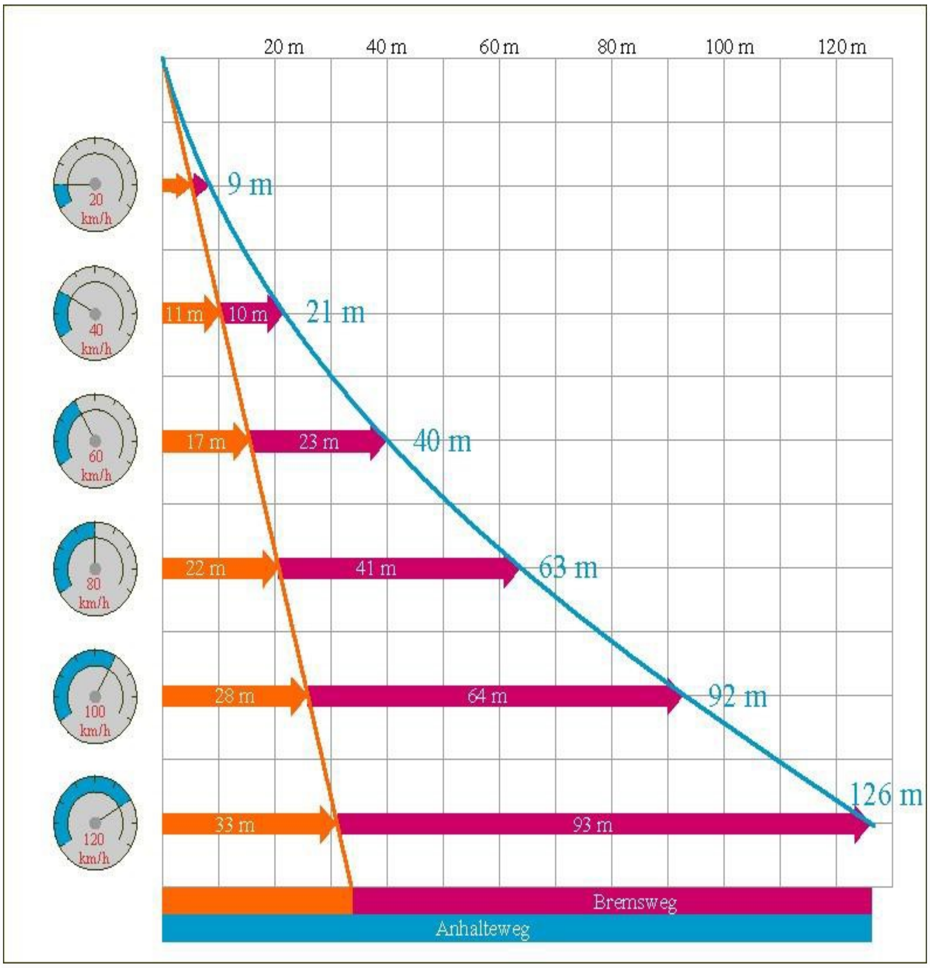
TCS, Alcohol and consequences, page 2018,2

STOPPING DISTANCE - INFLUENCING FACTORS

The stopping distance (AW) of a vehicle consists of the reaction distance (RW) and the braking distance (BW). The RW (from the perception of danger to the occurrence of danger) of the braking deceleration) behaves linearly and depends on the speed traveled as well as the reaction time. The BW is influenced by many factors (u.

a. Speed, weight, braking system, tire grip, road conditions, road gradient, etc.). (AAIB,

Physics in Road Traffic, 2008)



FigureInternet, https://www.leifiphysik.de/mechanik/lineare-bewegung-equations/outlook/stopping-path (orange = reaction path)

The graph above shows indicative values. Two characteristics are to be shown with it:

1. In contrast to the RW, the **BW does** not behave linearly to the speed traveled, but it **quadruples** approximately at twice the speed. (**10** m BW at 40 km/h, m**41** BW at km/h80).

2. At higher speeds, it is mainly the BW that is decisive for the AW. (at 120 km/h **93** m BW to **33** m RW, **factor 3**). Conversely - the slower the driving speed, the smaller the influence of the braking distance on the stopping distance. The reaction distance then makes up the greater part of the stopping distance. (at 20 km/h, the RW is significantly greater than the BW). This rule applies up to a driving speed of

of approx. km/h40. At higher speeds, the ratio reverses and the braking distance is significantly longer than the reaction distance. As a guide value for the reaction time, one second is generally assumed. To shorten the AW, we have two possibilities: We can reduce the speed (influence on RW and BW) and/or shorten the reaction time by being ready to brake. This can shorten the reaction time by up to two thirds (1/3 s). **Alcohol consumption and/or distraction** (cell phone, inattention, etc.) can also **increase** the average **reaction time to** three, four, or even more seconds. (https://de.wikipedia.org/wiki/Reaktion_(Traffic events) This can have **fatal accident consequences, especially in urban traffic** and low **speeds. Consequences that might not have occurred at all without distraction, alcohol consumption, etc.**

For me, the conclusion of the causes of accidents for practical lessons is that, in addition [illegible] distance/residual speed) and **distraction** (reaction time/away) must also be a topic in the VR velo simulator.

VIRTUAL REALITY

DEFINITION

Virtual reality, or VR for short, is the representation and simultaneous perception of reality and its physical properties in a real-time computer-generated, interactive virtual environment. VR is enjoying increasing popularity and has long since been used not only in the entertainment industry or in video games. A classic is certainly the application for pilot training in flight simulators. In principle, there are practically no limits to the use of VR technology. The user is in a virtual world, but this is considered plausible if the interaction is correct and logical. The software must be as faithful to the rendering as possible in order to appear believable. To create a sense of immersion (embedding the user in the virtual world), special output devices called VirtualReality headsets, a type of "goggles" with integrated projection, are needed to display virtual worlds. To create a spatial effect, two images are generated and displayed from different perspectives (stereo projection). Then the respective image is fed to the correct eye. In addition, special input devices are required for interaction with the virtual world. In the present case, a bicycle on a roller with various sensors to act in the virtual world, e.g. to accelerate, brake, steer. Special 360° films are needed so that the user can move freely in the virtual space, which must be recorded in advance with a special camera. The programs must be able to calculate complex three-dimensional worlds in real time and stereo (separately for left and right eye). This places high demands on the processor performance, especially in the driving simulation (bicycle simulator), in order to exclude or if possible reduce nausea, the so-called "motion sickness" (Internet, Wikipedia).

STUDY ON THE EFFECTIVENESS OF VR-GLASSES IN TRAFFIC INSTRUCTION

As mentioned in the introduction, a pilot project on the effectiveness of VR glasses in traffic instruction was scientifically accompanied and evaluated by the ZHAW. 6 School classes from the city of Zurich, 6th grade level, were taught by the school instruction with instructional films on the topic of recognizing dangerous situations with the bicycle. One half of the class was taught classically (beamer); the other half with the latest VR glasses and the corresponding 3D films.

The conclusion from the study: While the VR group tended to record better values in alertness and satisfaction as well as in the mention of the shoulder glance, the "beamer group" was able to remember significantly better the recommended actions of the traffic instruction that were not directly the subject of the films. (e.g., be ready to brake, drive slowly). The main reason for this difference is obvious: the school instructors were familiar with the classic lesson, whereas the VR lesson was new territory and therefore even less conclusive. Point 4.1 Conclusion of the study goes on to say: The **decisive factor** seems to be the **content** with which such new devices are filled and how they are finally **used in a meaningful way in** the **educational field**. The present study supports the fact that **VR glasses** also **have** precisely this **certain potential for imparting knowledge.** However, it shows that the mere use of VR **cannot** replace the personal contact with the school instructor and their classical teaching, but can **usefully complement** it. (Cordin et al., pp. 2019,ff45).

VR VELOSIMULATOR

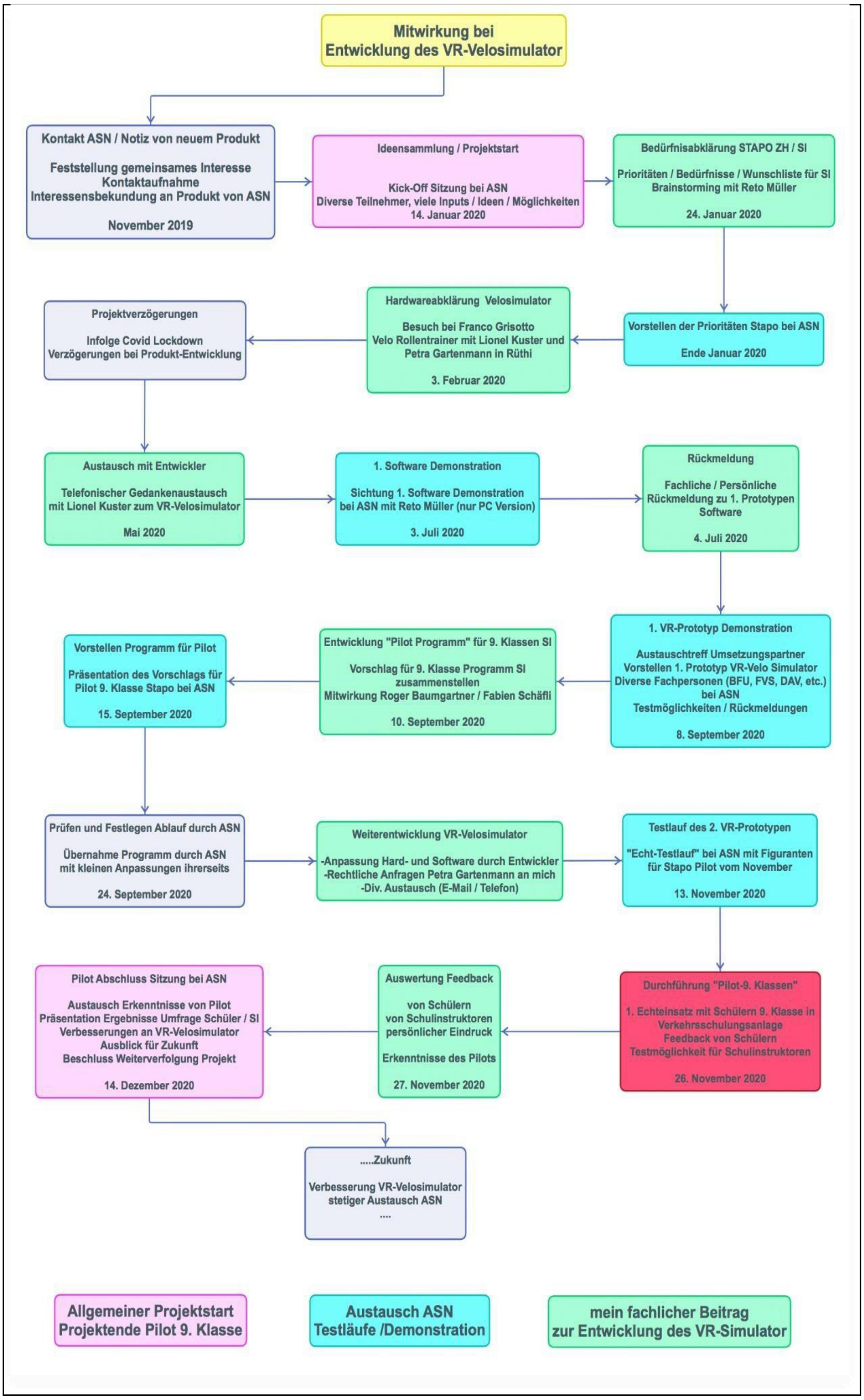
PLANNING AND DEVELOPMENT

With the goal of successfully using the VR velo simulator in 9th grade classes, the device basically had to be developed first. In the process, I had the opportunity to accompany and actively participate in the entire project.

Contact / Motivation

After I learned that ASN was planning to develop a VR velo simulator, my interest was piqued and I contacted them. The managing director of ASN, Chantal Bourloud, appreciated my interest in the project. After further discussions, I was invited to the kick-off meeting as a "project partner". I was excited by the idea and the possibilities that were revealed. It was immediately clear to me that I wanted to take advantage of this opportunity and pursue the project. This is because the use of a VR bike simulator in existing lessons could potentially add value.

The following schedule shows an overview of the different development steps.



The "heart" for the planned teaching unit is the VR velo simulator. The company, Virtual-Reality Learning GmbH, owner Lionel Kuster, was entrusted by the ASN with the development and realization of the VR-Velosimulator. In January 2020, the kick-off meeting for the project took place. According to ASN, this is a first development in this form in Europe. Accordingly, the project is challenging, but at the same time free in its development. After the presentation of the project idea by the ASN, the expectations, the wishes, the requirements etc. for the VR simulator were presented by all participants. In the process, a colorful bouquet of ideas for the hardware and software came together. The collected inputs, ideas and comments were collected and processed by the ASN and later sent to all participants. The task was to analyze the inputs, prioritize them and then compile a list of needs for its application or use. The result on the part of the Zurich City Police:

Hardware

- Real bike or home trainer (compact in terms of space/transport)
- Seat height easily adjustable for TN
- Realistic steering as well as drive
- External large screen for "passive TN" and school instructor
- Realistic braking (e.g. use of only one brake leads to longer BW)
- Ease of use

Software

- User-friendly/self-explanatory software
- Program structure Fixed program or with trigger (trigger points)? Both possible? 1 program with trigger / several simulations with fixed sequence? Control possibilities TN? How? Preset programs
- Aborting the ride must be guaranteed at all times
- Simulation of driving ability, speed differences (e-bike with 45 km/h vs. bicycle with km/h22, distraction (cell phone, music etc.)
- Can be coupled with real dangers in road traffic (e.g. opening car door, car turning off, truck (blind spot), reversing car, streetcar tracks, running red lights, lack of shoulder vision when turning left, wearing headphones)
- Visibility issue, lights/clothes (how feasible? Danger from other unlit cyclists?).

- Willingness to stop at pedestrian crossings (frequent lack of willingness on the part of cyclists)
- Participant with VR glasses looks at his "simulated" hands on the bike handlebars
- Hand signaling convertible? How? Physical behavior and visual reaction in VR must be as identical as possible (e.g. hand signal, arm visible, etc.)

I presented the "wish list" of the school instruction for a VR velo simulator of the ASN. This to clearly present the points. The ASN included the points in their list of requirements and passed it on for development.

Two central elements for the VR simulator are the speed decrease and the safe stand of the VR velo simulator. At my request, Franco Grisotto (recreational cyclist/friend of mine) enthusiastically demonstrated his indoor roller trainer with speed reduction. The project manager Petra Gartenmann and Lionel Kuster thus gained an important, first impression of a possibility for the fixation of the bicycle and a true to original decrease of the driven speed.

In June, ASN presented a first visual representation of the software on a PC screen. The illustrations were very realistic and showed a positive first impression.

TEST DRIVE WITH THE FIRST PROTOTYPE

At the beginning of September, the time had2020 come. Together with other selected experts from BFU, ACS, FVS, DAV etc. I was invited to the presentation of the 1st prototype. The bike, fully wired and apparently still a prototype, could be test ridden in three scenarios:

1. Scenario:Acar reverses from the right out of a parking space into our bike lane
2. Scenario:Atruck crosses our bike lane without warning when turning right (blind spot with perspective change cyclist/truck driver).
3. Scenario: When passing a stationary line of vehicles, the passenger door suddenly opens

All three scenarios represent a sudden danger for the cyclist. Langstrasse in the city district was chosen5 as the location. After the presentation were discussed by the participants picked up the opinions and impressions. Those who tested the VR simulator were impressed by what they experienced, some felt a little woozy in the head (motion sickness). I also felt a sinking feeling in my stomach during the emergency braking, but it quickly passed.

Test drive first prototype at ASN, September (2020l. Lionel Kuster, Ch. Schällibaum)

My personal impression:

- Impressive experience with potential for multiple uses
- Velo stability still needs to be improved (risk of tipping possible during abrupt maneuvers)
- The time from getting on the bike to being ready to leave must become shorter
- Hardware and software must be improved (e.g. bar charts are displayed too small)
- Revise and adapt scenarios

PLANNING THE PRACTICAL APPLICATION

It was agreed with the ASN in advance that I would be allowed to use the prototype on the occasion of a pilot project during the lessons in the 9th grade. I was given the opportunity to put together a desired sequence with adapted content/scenarios for our training.

My main work could begin.

My thoughts were as follows: How can the aforementioned rough and fine objectives be implemented in minutes20 of instructional time? What might an actionable, logical lesson flow look like? Which "danger triggers" are realistic, implementable and have a great "aha effect" on the students? How can as many students as possible actively experience the VR simulator themselves in this very short lesson sequence of 20 minutes?

The main challenge for me is the short teaching time of only 20 minutes per group with about 7 students. Furthermore, we will work with **a VR bike simulator at** the pilot. With the **scooter driving simulators** we have used so far, we had **eight driving simulators** available. In this way, **all students** could **actively** try out and experience at the same time, which will **not** be **possible** with the **VR simulator,** since there is only one Pilot device. It is uncertain whether it will be possible to train with several VR driving simulators at the same time in the future for logistical, technical and, above all, methodological reasons. At the moment, I cannot imagine a practical implementation with several devices for the aforementioned reasons.

I intensively dealt with the questions regarding the implementation. As a result, I presented the following topics at the ASN in September:

- **Reaction time** (perception of danger until braking)
- **Stopping distance**: reaction distance plus braking distance (bar chart)
- **Alcohol/stimulants** o Comparison of 5sober/alcoholized0 (0. 2/0. /. 8/1. 2per mille)
  - o Switchable visual effects tube vision/blurred, effects on RW, BW, AW while driving.
- **Distraction** (e.g. cell phone)
- **New scenarios** (car door of a parked vehicle on the right instead of the stationary column on the left, truck was replaced by swerving car on bike lane)

These topics are to be implemented in a sequence as follows:

Student (A) is actively riding on the VR simulator. The other students observe his behavior and reactions on the bike and also on the flat screen. This reflects the visual field of the cyclist. After a few seconds of riding, a dangerous situation is triggered (Trigger X1), as could happen in everyday cycling (3 Driving settings, p. 26). This is followed by a reaction of the student (A) to the dangerous situation. Then the simulation ride is ended, the VR goggles are removed and the sequence is discussed in plenary. A change is made.

Student (B) starts on the same course at the identical starting point. However, under the simulated influence of alcohol. The passive students now expect at most the same danger as in the example1. with student A. However, nothing happens at this point. Only later on the track a dangerous situation occurs (trigger X2), but it is different from the first student. Student (B) reacts, the simulation is stopped and the sequence is reviewed again in plenary with all students.

Pupils (C) follows. Same route, same starting point. The topic is distraction by a cell phone. The hazard trigger is again different (Trigger X3). Surprisingly, this hazard appears earlier than in the first two test riders, which surprises many participants. After discussing the ride in plenary, the conclusion and the conclusion of the teaching unit follows.

In summary, there are **different driving 3settings** (**A** = **sober**, **B** = **drunk**, **C** = **distracted**), on the **same driving route** with **different hazards** (trigger points X1, X2, X3) at different locations.

Topic	**Distraction (mobile phone/sober)**	**Stopping distance in general (sober)**	**Alcohol (alcoholized)**
Trigger	**X3**	**X1**	**X2**
Danger	**Car shears off**	**Car drives backwards**	**Car door opens**

(Student A) Stopping distance in general (car reverses into our lane).

- Brake readiness
- Response time
- Collision / no collision (topic stopping distance, reaction distance, braking distance)
- Lack of experience/traffic sense
- Comparison diagram with/without alcohol (residual speed on impact)
- (possibly and 2.passage3. with other speed (e-bike with km/h45), influence of speed on stopping distance

(Student B) Alcohol (car door on parked vehicle suddenly opens)

- Collision (mandatory because under the influence of alcohol)
- Question of guilt vs. consequences of accidents (injuries)
- Comparison sober/alcoholized (show table/bar chart)
- Residual speed compared to sober (possible?)
- Alcohol limit for new drivers, general, cyclists
- Alcohol and physical consequences (tunnel vision due to restricted field of vision, difficulty focusing the eyes, impaired balance, increased risk-taking behavior, etc.).)

(Student C) Distracted cell phone (sober, TN is distracted by cell phone (rings, answers) at the same moment a vehicle swerves to the right onto bike lane).

- Reaction time without distraction? Reaction distance, stopping distance, residual speed
  Danger☐ detected without distraction?
- Pointing out consequences of distraction, what's a second....
- Gaze behavior
- Only one hand on the brake lever (longer braking distance, rollover possible)

The suggestions for the Pilot 9th grade lesson were openly received and discussed at the round table with the project participants. The idea of different accident triggers/scenarios on the same route in different driving conditions was found to be good and was followed up. Nevertheless, some questions arose for me when considering the procedure: How can the measurement criteria be compared with each other if not all participants are driving at the same speed with the VR simulator? Is it possible to adapt the accident triggers to the speed of the TN (variable control)? How can the rather low driving speeds be used to impressively demonstrate to the participants that the braking distance quadruples at twice the speed? How can the "mental" adaptation of the participants to a passenger car, motorcycle or scooter be achieved?

Determination of the procedure with the ASN

The project team, led by Petra Gartenmann, reviewed what they already considered a very coherent proposal. Based on this, only minor changes were made. Lionel Kuster and his team of developers now programmed a new track with the three triggers according to the new ASN specifications. The new route is no longer Langstrasse in District 5, as was the case with the first prototype, but Dörflistrasse in District 11 near Hallenstation. The advantage: Dörflistrasse has several lanes, can be driven at km/h50 and has a slight gradient. The cyclists drive accordingly almost at the same speed as the rest of the traffic. In comparison to Langstrasse, Dörflistrasse has a bicycle lane.

TEST DRIVE WITH THE SECOND VR PROTOTYPE

After the game is before the game, as they say in soccer circles. It's probably similar in development. After the test run of the 1st VR prototype (and the evaluation), the development of the 2nd VR prototype followed. In the past two months, in addition to adapted software, the hardware, i.e. the VR bike was completely replaced by a new bike and the cabling, sensors, etc. were adapted.

In order to put the VR simulator through its paces before its first real use with participants, a test run was carried out at the ASN with test persons. Operating the simulator (still) requires special knowledge, which is why Petra Gartenmann took over the moderation. We were all delighted, because the test run lasted 16 minutes and was successful.

The VR Velosimulator was now ready for its first real use!

PRACTICE SECTION

CONDITION ANALYSIS

I planned to conduct the pilot lesson during the regular training sessions in the winter half-year at the traffic training facility of the city of Zurich. Three graduating classes of the Feld school building in district 4 were pleased to participate on November 26. In addition to arranging the dates, I explained the procedure and the special features of the pilot to the teachers. Among other things, this was with regard to the evaluation. Furthermore, the following points had to be considered in the planning and execution:

SuS = Pupils

TAXONOMY

Based on the defined sequence of the ASN, the lesson plan was created. This contains the chronological sequence of the lesson.

Regarding the complete procedure of this double lesson, I refer to the fact sheet and the explanations, page 9 ff. After the welcome and the theoretical introduction, the class is divided into three groups, one of which experiences the VR bike simulator with a school instructor.

Time [min]	Content / Substep	Activities Input Processing Control	Material	Who
1	**Covid-19 protective measure:** Disinfection	Classroom teaching	Disinfectant	SI TN
1	**Explain procedure** Present VR simulator	Class teaching (I)		SI TN
2	**Preparation** Student (A) takes seat on VRVelo, adjust saddle height, put on VR goggles	Class teaching (I)	VR Simulator (PC, screen, fan) Whiteboard	SI TN
4	**Pupil A: Stopping distance** (car swerves to the right onto bike lane) (A) drives off (sober) experiences ☐ danger ☐ reactionResult? *Topics:* Collision, braking readiness Reaction time RW/BW/AW Influence speed on BW	Simulation drive (active: student1) (passive: remaining students) Classroom teaching Teaching talk (I+V+K)	VR Simulator (1st example) Evaluation diagram RW/BW/AW Whiteboard/Icons	SI TN
2	**Change student for VR simulator** Disinfect VR goggles, adjust bike, put on VR goggles	Class teaching (I)	Disinfectant	SI TN
4	**Pupil B: Alcohol** (TN drives under the influence of alcohol to the right parked vehicles, car door suddenly opens) (B) drives off. Experiences ☐ DangerReactionResult ☐ ☐ Collision Topics: Question of guilt/injuries, comparis on RW/BW/AW, influences alcohol?	Simulation drive (active: student1) (passive: remaining Pupil) Classroom teaching Teaching talk (I+V+K)	VR Simulator (2nd example) Evaluation diagram RW/BW/AW	SI TN

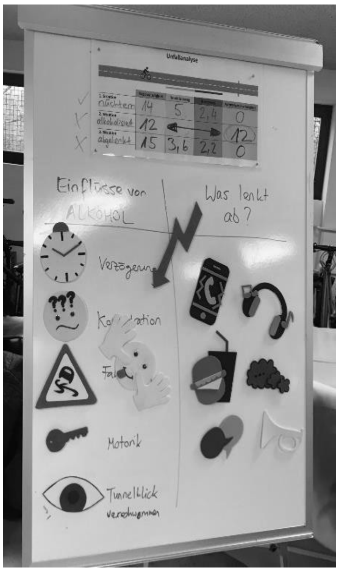
	Vision (tunnel vision, etc.), distance to parked vehicles, bridging to PW, motorcycle, risky behavior of young people, group dynamics, reasons (risk taking, lack of experience and driving with foresight), diagram fatal accidents BFU, alcohol limit for new drivers.		(Fade in field of view) Whiteboard/Icon *Statistics BFU A3 Format (lethal Accidents/alcohol/age groups)*	
2	**Change student for VR simulator** Disinfect VR goggles, adjust bike, put on VR goggles	Class teaching (I)	Disinfectant	SI TN
4	**Pupil C: Distraction** (pedestrian crossing the road between stationary cars) (C) drives off is □ distracted □ by ringtone looks down on cell phone (handlebars), at the same time a pedestrian appears between the cars and crosses the road in front of him reaction result collision Topics: Distraction, reaction time, danger detected without distraction? Distraction as a general problem on the roads. What all distracts us? Gaze behavior, RW/BW/AW, consequences distraction (what's a second...), conclusion questions, Conclusion	Simulation drive (active: students1) (passive: remaining students) Classroom teaching Teaching talk (I+V+K)	VR simulator (3rd example) Evaluation diagram RW/BW/AW Whiteboard / Icons	SI TN

(SI = school instructor, TN = participant/student).

IMPLEMENTATION OF THE PILOT PROJECT WITH ASN

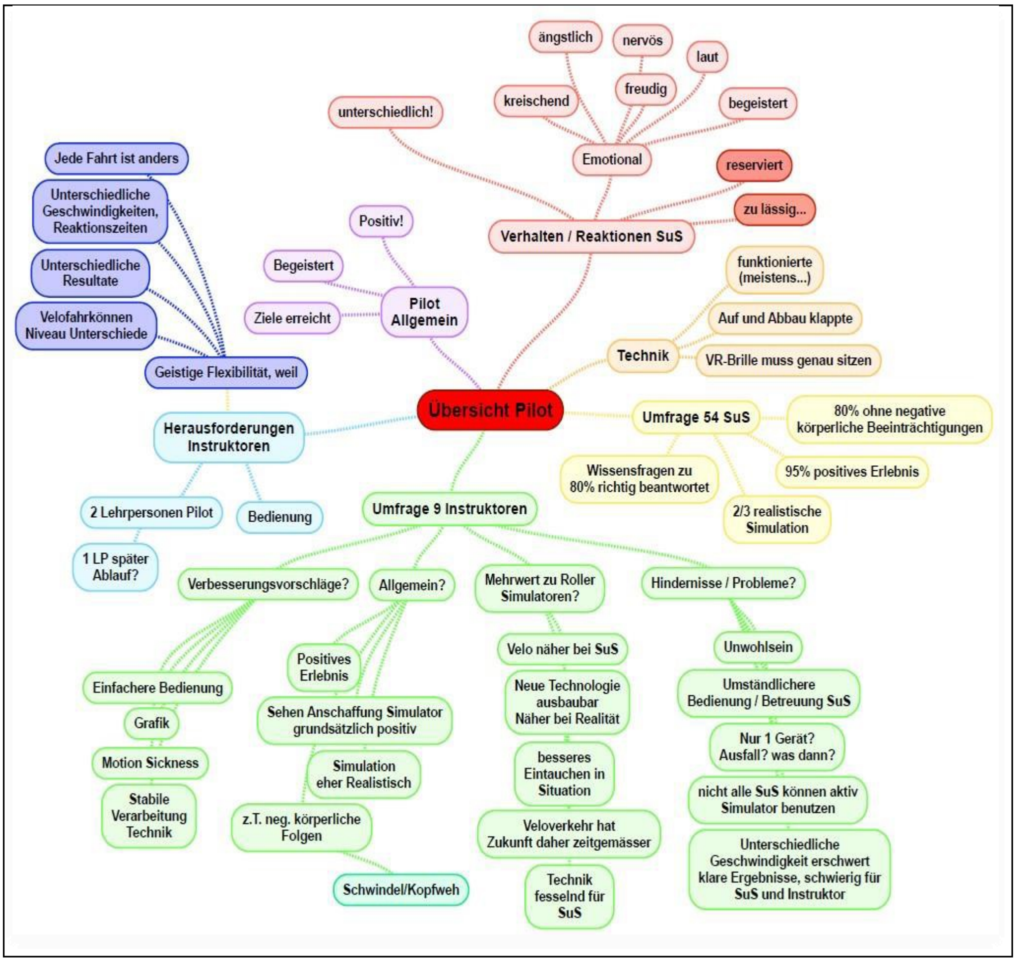
The operation of the simulator still requires in-depth knowledge. Therefore, the ASN offered to support us with the training. Petra Gartenmann took the lead, while Chantal Bourloud and I did the co-moderation. With anticipation, we awaited the three classes on November.26.

Impressions from the lessons



RESULTS AND REACTIONS

The following mindmap contains impressions and insights:

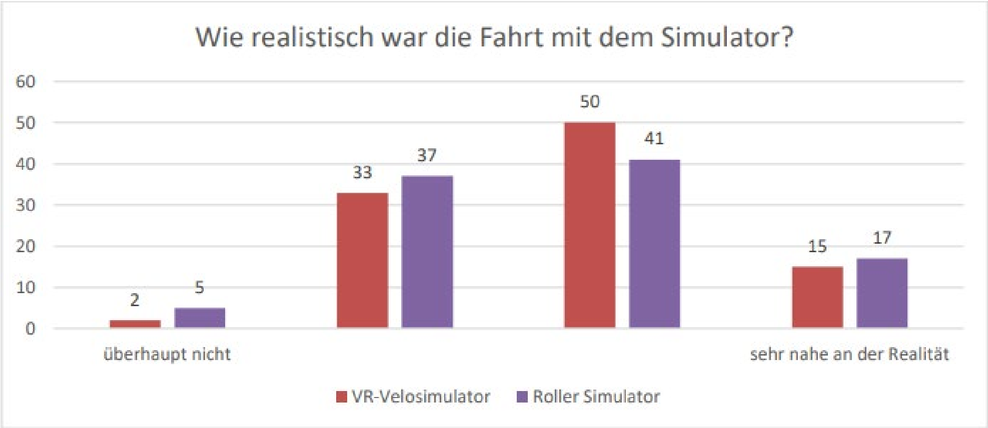


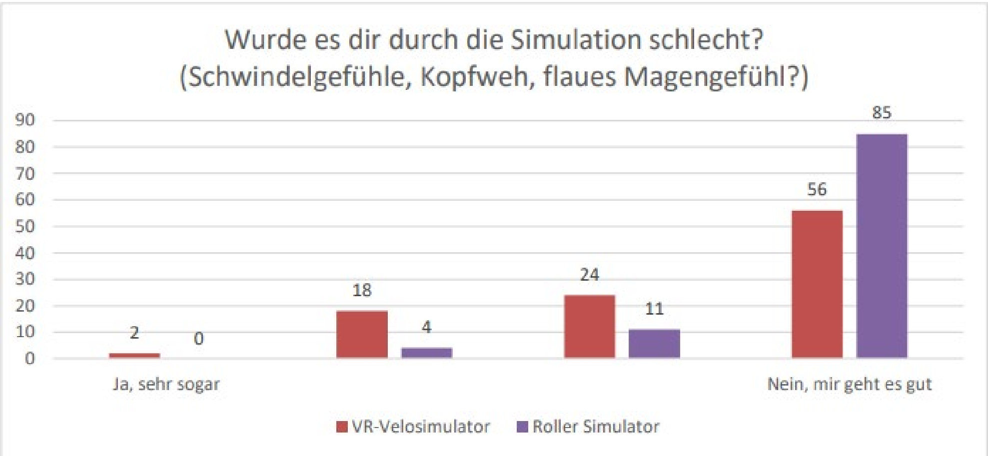
Apart from the fact that the first class appeared fifteen minutes late and put us under time pressure, the pilot day went smoothly and satisfactorily. The students of the three classes were motivated and enjoyed the lessons. The reactions were very different as seen above. The first class was very emotional. For example, the very first participant shrieked loudly and was visibly excited while driving on the simulator. The 2nd class was reserved and had to be motivated to drive at times. The afternoon class was then an average of the first two classes. The cognitive driving skills of the students on the simulator were also very different. Everything was there: different driving speeds, gaze behavior, lane behavior, perception of hazards, braking behavior, etc. So it stands to reason that this would lead to different results. This in turn challenged the facilitators and required them to quickly adapt what they had experienced. Petra, who took over the main moderation, mastered these pitfalls with aplomb. Together with the co-facilitators Chantal and myself, we succeeded in working through the experience with the students and extracting the relevant insights.

STUDENT SURVEY / COMPARISON WITH CLASSICAL TEACHING

The 54 VR Pilot students participated in an online survey (Google Forms) with nine questions (see Appendix for questions and results). To also get a direct comparison with the conventional scooter driving simulators, 46 other students were surveyed on December 7. These were taught the "conventional way," came from other school buildings, and were also taught by other school instructors. Among other things, the students were asked about realism and motion sickness.

HOW REALISTIC WAS THE RIDE WITH THE SIMULATOR





In terms of realism, the VR velosimulator is rated better, but the disadvantages of the VR velosimulator in terms of motion sickness outweigh the scooter driving simulator. The ninth open-ended question was "Last, your opinion. What can we do better?" Enclosed are some statements (VR velo simulator survey only): "Everything was good", "Thank you", "That everyone can try it", "Improve the graphics", "I liked it a lot and it was fun", More time because I couldn't ride a bike", "Nothing, nada", "Nothing, it was great".

COMPARISON OF ACTIVE AND PASSIVE PARTICIPANTS IN THE VR VELOSIMULATOR

Due to time constraints, not all students could actively experience the VR simulator on the bike. Out of a total of 54 students, 29 actively experienced the VR bike simulator, 25 passively as spectators on the big screen. Since this represents a significant difference in the lesson, I expected large differences in terms of realism, fun factor, and sensitivities. Surprisingly, there was not much difference between the two groups in terms of realism. The active participants had slightly more fun than the passive participants, which was to be expected. On the other hand, they were twice as likely to feel nauseous, dizzy or have a headache, which was equally unsurprising. Finally, the fear that there were many disappointed students who could not actively ride did not prove true. My personal impression while observing this was also that some students were rather happy not to have to drive.

PROFESSIONAL FEEDBACK SCHOOL INSTRUCTORS

Spontaneously, 9 school instructors took the opportunity to experience the VR velo simulator as participants. Their feedback is important to me and is detailed in the mind map (p. 32). The most important findings from this survey: they enjoyed using it; motion sickness was more pronounced than among students (2 complained of headaches/dizziness), six can imagine teaching with the VR simulator, three as well after closer examination. The new technology and thus a better immersion in the situation is mentioned as added value. Many see the more complex operation and moderation as well as motion sickness as a challenge. As an improvement, the school instructors would like to see visually improved graphics, easier operation and a reduction in motion sickness.

EVALUATION WITH THE ASN

Chantal, Petra and I agreed that the pilot had been successful and positive. I presented the student evaluation and the professional feedback from the school instructors. During the professional exchange, we discussed some points that had come to our attention and needed to be improved or were already being adjusted:

- Improvement of motion sickness by: acoustic braking sounds, ventilator driving wind, better starting mode, vibro plate for stand (road unevenness)
- Improved lateral stability due to additional supports at the rear

- Simpler operation (e.g. through interface menu guidance)
- Smaller gear ratio
- Low-entry bike (also suitable for older participants)
- Develop possibility to carry out the moderation alone
- Improvement of graphics (e.g. bicycle lanes clearly recognizable as such)
- Separate program brake test/stopping distance
- More effective distraction by cell phone, text message instead of ringing tone (push-up message)

"Can a newly developed VR velo simulator be incorporated into an existing teaching unit on driving skills?" This was the first question of my work. Yes, I think so. Thanks to the technology, the moderation and a coherent process, it is possible to impart valuable information to the students in an impressive way, even in a very short time window.

The second question concerns the added value of the VR velosimulator compared to the conventional scooter driving simulator. This question is more difficult to answer. The survey of the students also shows this. Whether an added value results, depends in my opinion strongly on the respective presenter. Further, due to time constraints, all students will never be able to actively ride, and the immersion in this virtual world is unfortunately denied to some of them. The goal of a simulator is to experience reality as closely as possible. And that is what the VR- Velo simulator offers. Through the further development of the VR velo simulator, it can be assumed that the technological added value will increase. If, thanks to this added value, we succeed in showing students the effects of alcohol and distraction in road traffic even more impressively than before, then I will also answer this question with a yes.

A look into the future

This one is gratifying. Through the ASN, the VR velo simulator is being further developed. The points listed above will be implemented in the coming months. In spring 2021, the Kapo Bern will use the VR-Velosimulator (status prototype) to carry out various preventive operations in its territory. Interest in the VR-Velosimulator has increased among various accident prevention providers. More localities will be added by summer 2021, as well as a separate brake test program. ASN's goal is to be able to present and offer reliable VR velosimulators for real-world use by the end of August 2021. With a view to using the VR velo simulator increasingly for the training courses of the Zurich City Police on the topics of alcohol and distraction, I will remain in contact with the ASN and continue to follow the development closely.

Support

I would like to express my sincere thanks to the ASN, especially Chantal Bourloud and Petra Gartenmann, who made this thesis possible and gave me the chance to be an active project member from the very beginning.

I would like to express my appreciation to Lionel Kuster, who finally put the thoughts and suggestions into practice in the programming and development of the bike simulator.

I would also like to thank Denise Gasser, who enthusiastically supported and motivated me in writing this paper.

I would also like to take this opportunity to thank my colleagues from the school instruction of the Zurich City Police for contributing their ideas and expertise. Special thanks go to Reto Müller, Fabien Schäfli, Ruben Ruiz and Roger Baumgartner.

I would also like to thank Dr. Wernher Brucks for his competent advice and information. I would also like to thank Franco Grisotto for demonstrating his bike and Gianni Ganahl for his support.

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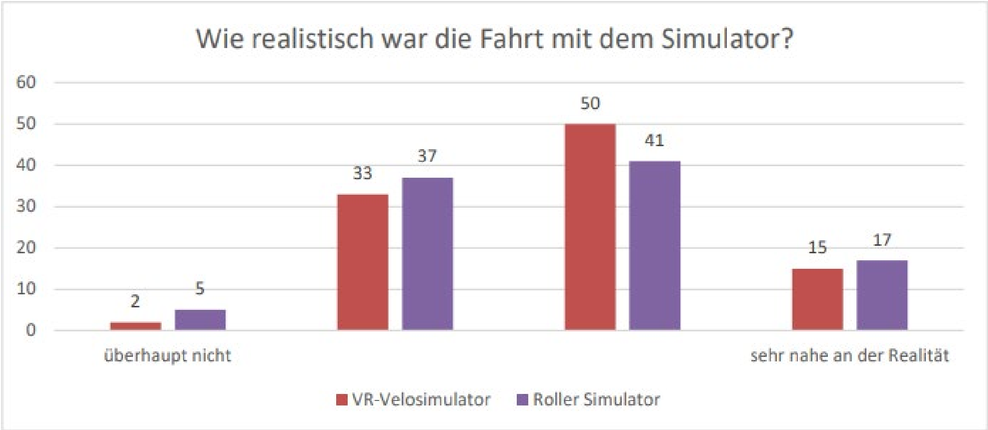
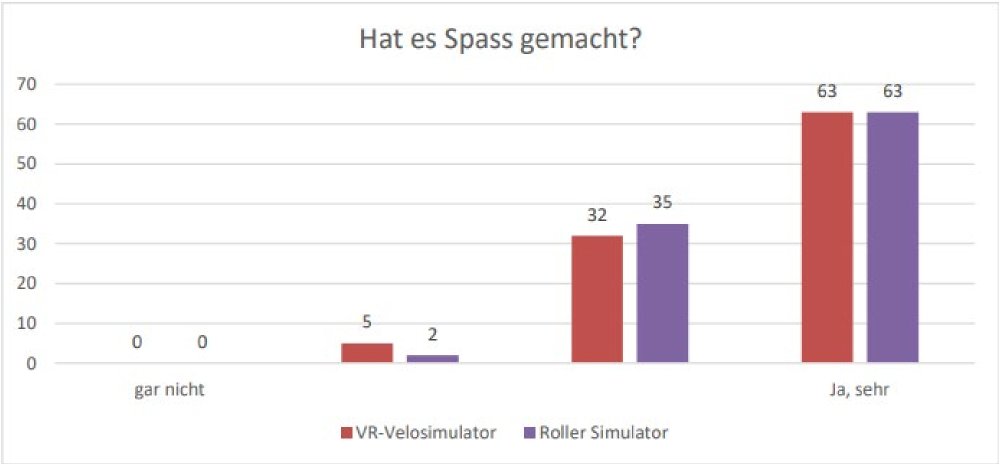
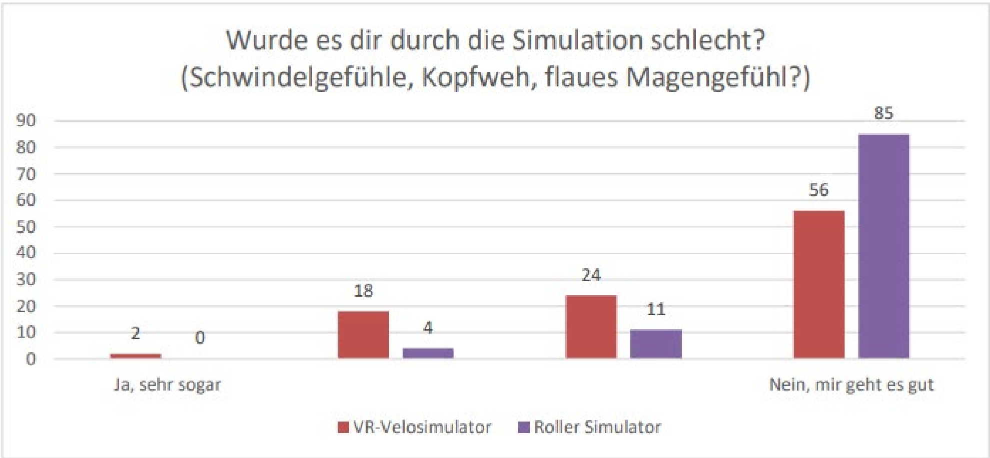
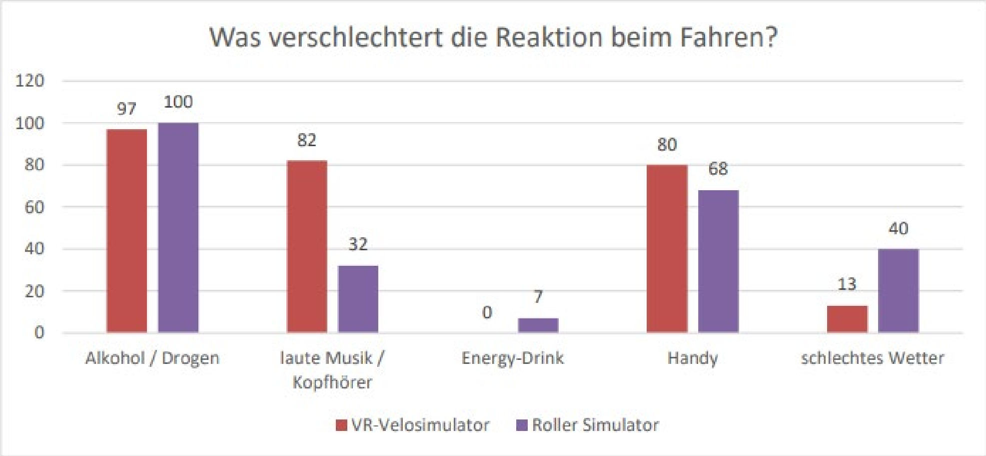
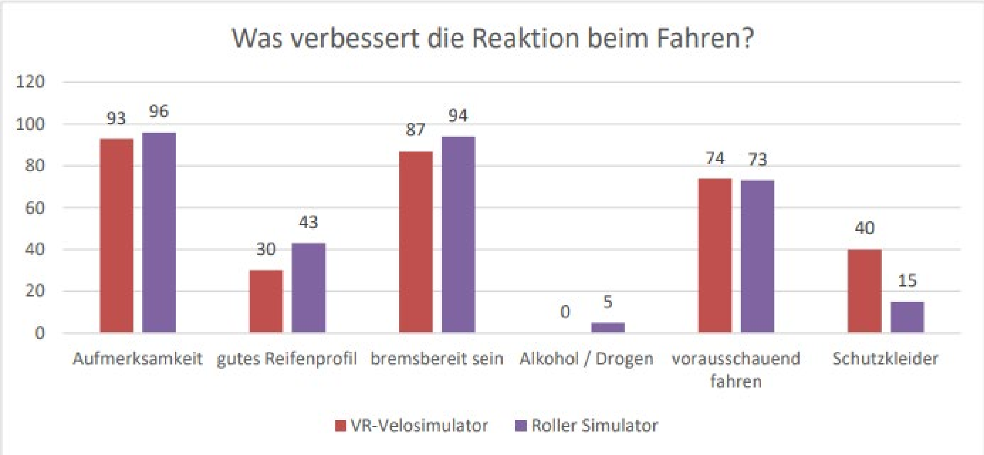
Results of the student survey (all figures in percent)

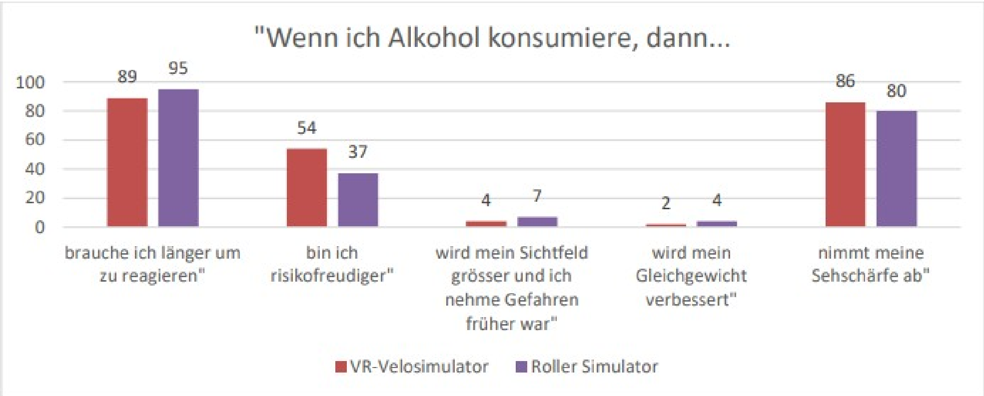






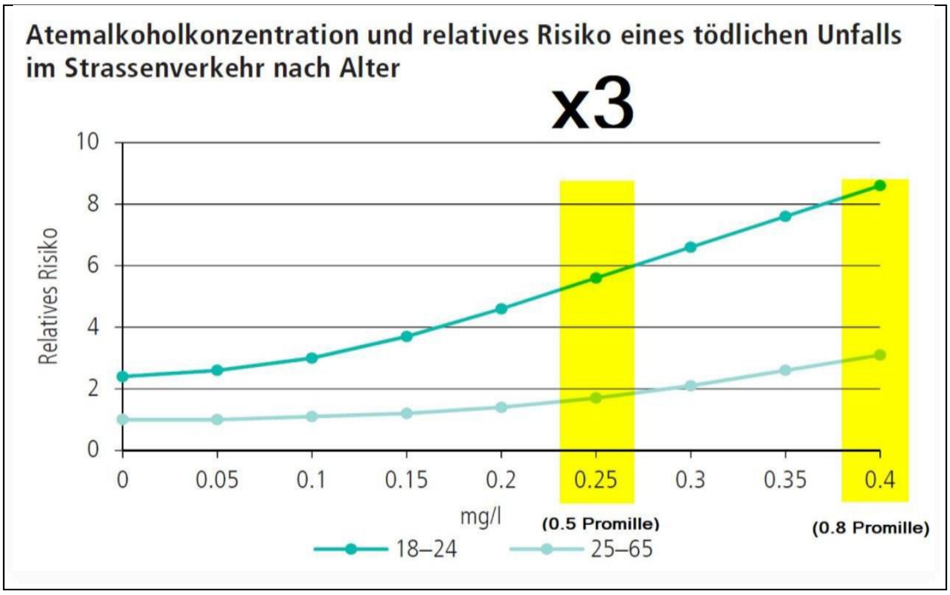




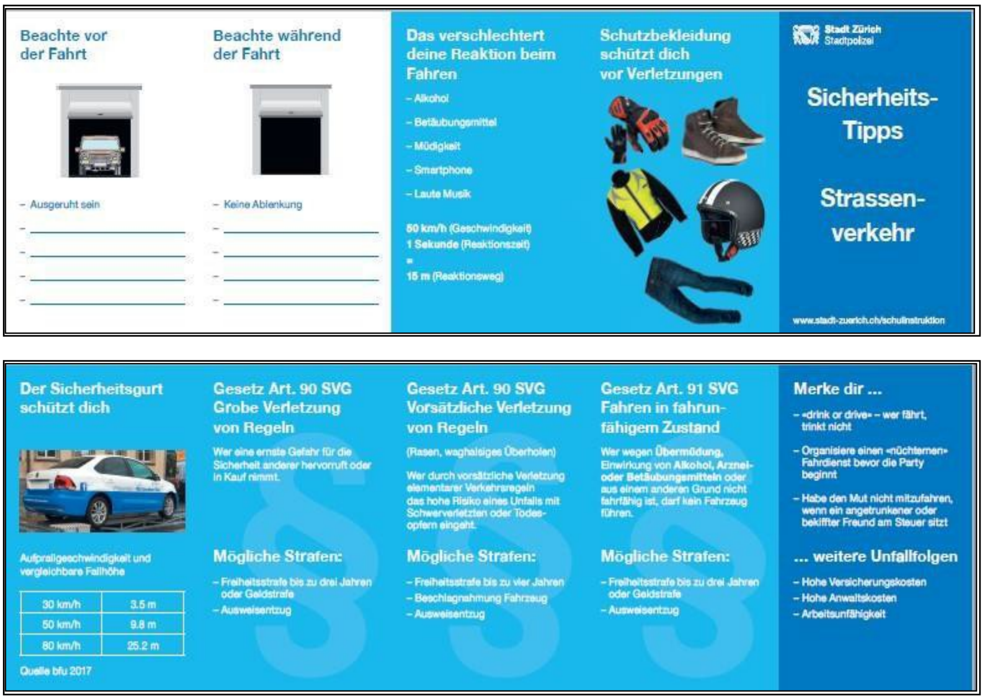


The ninth and final question in the online survey was, "Last, your opinion. What can we do better?" 19 Students responded to this question. of which17 made a specific statement, most of which was positive, as mentioned on page 34. Three students would like more time because they could not ride the VR Velosimulator. Two would like improved graphics.

Teaching aids



Source: BFU, Status 2019, page 24



Zurich City Police (2019), Miniflyer, Safety in Road Traffic

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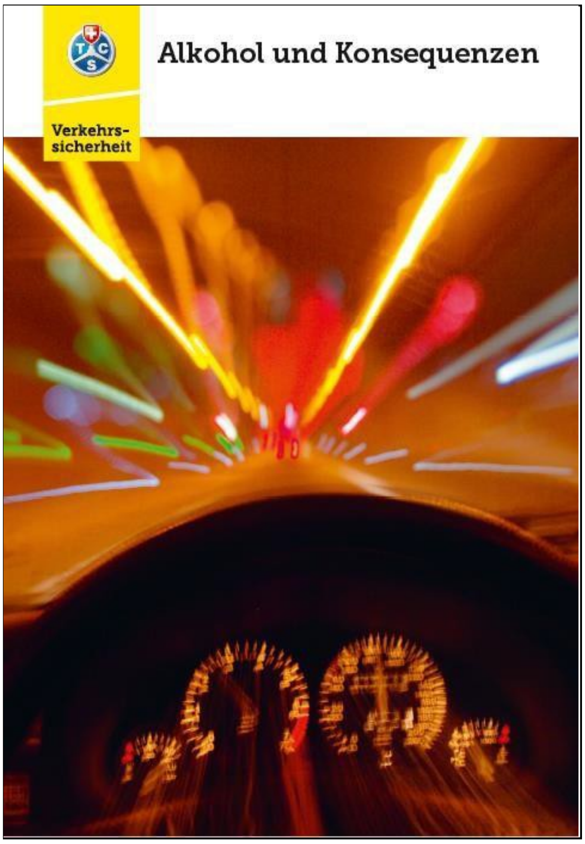
BFU (2018), poster, alcohol campaign - Who drinks, does not drive - beer glass / wine glass



Touring Club Switzerland (2018), brochure

At the wheel Never, scratch card alcohol, format A5

Keywords: VR bike simulator, VR bike, VR driving simulator, prevention bike, prevention traffic, prevention bike accidents, prevention and awareness, simulation traffic accidents, prevention road traffic.