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Tools for Naturalistic VRU Study - Hands-on Manual

Madsen, Tanja Kidholm Osmann; Agerholm, Niels; Várhelyi, András; Bahnsen, Chris Holmberg; Jensen, Morten Bornø; Laureshyn, Aliaksei; Moeslund, Thomas B.; Lahrmann, Harry Spaabæk

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InDeV: In-Depth understanding of accident causation for Vulnerable road users

HORIZON 2020 - the Framework Programme for Research and Innovation

Deliverable 6.2

Tools for Naturalistic VRU Study
Hands-on Manual

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PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Document information

Authors

Tanja K. O. Madsen, Aalborg University, Denmark
Niels Agerholm, Aalborg University, Denmark
András Várhelyi, Lund University, Sweden
Chris H. Bahnsen, Aalborg University, Denmark
Morten B. Jensen, Aalborg University, Denmark
Aliaksei Laureshyn, Lund University, Sweden
Thomas B. Moeslund, Aalborg University, Denmark
Harry Lahrmann, Aalborg University, Denmark

Project Coordinator

Aliaksei Laureshyn

Department of Technology and Society

Lund University

Box 118

221 00 Lund, Sweden

Phone: +46 46 222 91 31

Email: aliaksei.laureshyn@tft.lth.se

Coordinator of WP 6

Evelien Polders

Transportation Research Institute (IMOB)

Hasselt University

Wetenschapspark 5

BE-3590 Diepenbeek

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Version	Date	Comment
1	18-02-19	Initial draft
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3	20-04-18	Revised document

The present document is a draft; the approval from the EU Commission is pending.

Table of Contents

1. Executive Summary

Accident data from official records such as police reports or emergency room data is affected by a large degree of underreporting, particularly for vulnerable road users. Naturalistic data collected automatically from the road users can be a means to overcome this problem. The large amount of collected data, however, necessitates the use of technology to facilitate data processing and analysis. This manual describes the three smartphone apps developed with the aim of getting more insight and knowledge in accidents among vulnerable road users based on naturalistic data. The apps and source codes are available via https://bitbucket.org/aauvap/vrumonitorapp/.

The VRUMonitor app was developed to detect accidents based on an analysis of the motion data of the phone. The underlying idea is that abnormal motion occurs in the event of an accident and that this motion differs from everyday activities. Due to the fact that different smartphones contain different motion sensors it is a complex task to make a fully functional system across all smartphone brands and models. Therefore, it has not yet been tested on a larger scale. In addition, the SafeVRU app was developed for self-reporting of accidents and near-accidents and has been used by more than 400 participants.

2. Introduction

Naturalistic studies are a means for collection of motion data via sensors in the vehicle or on the road user in order to study road user behaviour continuously. Typically, road user information (e.g. speed, performed manoeuvres, video footage of surroundings and of the road user) is collected continuously via equipment such as accelerometers, gyroscopes, GPS receivers, video cameras and/or switches connected to the vehicle.

Naturalistic studies often involve a large number of road users who collect data for a long period of time (months, years). Therefore, accidents and near-accidents will eventually be recorded, which can provide important information regarding the instants immediately before and during the incidents. With this information it is possible to get a better understanding of the underlying factors related to how and why accidents occur.

As naturalistic studies collect data from a large range of data sources and over a long time period, tools for facilitation of data processing and data analysis are necessary. Within the InDeV project, research was carried out towards the development of a system for automatic detection of accidents among vulnerable road users, particularly pedestrians and cyclists, based on motion data collected via smartphones. The approach of the development was to make a system consisting of two parts: a tool for automatic detection of accidents and extraction of accident information (e.g. time, location, motion patterns) and a tool for confirmation of the accident as well as registration of detailed accident information that cannot be registered automatically via the smartphone (e.g. who was involved, description of what happened, potential accident causation factors). The approach is illustrated below. Further details regarding the development can be found in InDeV deliverable D4.5 (Madsen *et al.*, 2017).

Automatic accident detection
Monitoring of road user movements based on smartphone sensors (accelerometer, gyroscope)
In case that an accident is detected, time, location and motion patterns for the accident will be stored

$\downarrow$

Self-reports of detailed accident information
In case of an accident detected, a questionnaire is sent to the road user asking him/her to provide additional information regarding the accident, such as
• mode of transportation • what happened in the accident • whether other road users were involved and their mode of transportation • weather conditions • road surface conditions • presence of potential accident causation factors (e.g. being influenced by alcohol/drugs/medicine, fatigue, distraction)

In this deliverable, the tools developed are described and illustrated with the intention to provide an overview of the data collected, how they can potentially be analysed continuously in an app for automatic detection of accidents of pedestrians and cyclists and how additional information can be gathered from the involved road users via questions in the smartphone app.

3. Technical tools

For the development of a system for automatic detection of pedestrian and cyclist accidents and additional information that cannot be collected automatically, three Android apps were developed; VRUMonitor Data Logger, VRUMonitor, and SafeVRU. The former was used primarily for the initial data collection in order to develop an algorithm for accident detection based on smartphone sensor data. The latter two constitute the core of the system; an app in which an algorithm for accident detection continuously monitors the motion of the smartphone and assess whether an accident has most likely occurred, and an app for self-reporting of accidents. The apps and source codes are available via https://bitbucket.org/aauvap/vrumonitorapp/.

Originally, the idea was to combine the two apps, so that the road user is monitored via the app, which, based on the motion patterns, then detects when they may have been involved in an accident as pedestrian or cyclist. In case of an accident, as much information as possible should be registered automatically (e.g. time and location) and a questionnaire should automatically be sent to the road user for confirmation of the accident and provision of detailed information of the accident (e.g. road surface conditions, lighting conditions, other road users involved). To make the development and testing of the apps easier, and as a consequence of the difficult process to make an app that works on all smartphone independently of operation system and sensor specifications, the two apps have been made separately with no connection in-between as a proof of concept.

3.1. VRUMonitor Data Logger

The VRUMonitor Data Logger can be used for collection of motion data from Android smartphones, either for short user defined intervals (e.g. 10 seconds, 2 minutes or 15 minutes) or until the user manually stops the data collection via the app interface. Appendix 1 describes how to use the app.

During the data collection the linear acceleration, rotation and orientation is logged in three axes (x, y, z) with a variable frequency depending on the sensors of the phone, typically 10-100 Hz. Furthermore, the location (latitude, longitude), the speed and the screen state (turned on/off) of the phone are logged. Figure 1 illustrates the raw data which is saved in a .txt file and Figure 2 and Figure 3 show an example of the acceleration and rotation data logged with the VRUMonitor Data Logger app.

Date	NanoTime	Identifier	Mode	X	Y	Z	msDifference	speed	screenOn	latitude	longitude
Tue Aug 16 14:05:19 CEST 2016	2176913941490630	Ck1	Bike	0,07499405	0,09610016	-1,1972104	2176913941	0	true	0	0
Tue Aug 16 14:05:19 CEST 2016	2176914011138120	Ck1	Bike	0,93780595	-0,80006486	0,00954944	69	0	true	0	0
Tue Aug 16 14:05:19 CEST 2016	2176914081792780	Ck1	Bike	0,70323837	-0,8074604	-0,13277061	70	0	true	0	0
Tue Aug 16 14:05:19 CEST 2016	2176914155133240	Ck1	Bike	0,63655424	-1,0131172	-0,04878444	73	0	true	0	0
Tue Aug 16 14:05:19 CEST 2016	2176914222033890	Ck1	Bike	0,59597504	-0,94532174	-0,12447269	66	0	true	0	0
Tue Aug 16 14:05:19 CEST 2016	2176914292413870	Ck1	Bike	1,0606296	-0,87328845	0,0961914	70	0	true	0	0
Tue Aug 16 14:05:19 CEST 2016	2176914362366570	Ck1	Bike	1,1304898	-0,7165825	-0,1159609	69	0	true	0	0
Tue Aug 16 14:05:19 CEST 2016	2176914432624460	Ck1	Bike	1,2992882	-0,70308954	-0,03188281	70	0	true	0	0
Tue Aug 16 14:05:19 CEST 2016	2176914502180390	Ck1	Bike	1,2148911	-0,6605191	-0,16521506	69	0	true	0	0
Tue Aug 16 14:05:20 CEST 2016	2176914572346730	Ck1	Bike	1,4133269	-0,5932508	-0,0937188	70	0	true	0	0
Tue Aug 16 14:05:20 CEST 2016	2176914642726710	Ck1	Bike	1,4856317	-0,5448678	-0,02427415	70	0	true	0	0
Tue Aug 16 14:05:20 CEST 2016	2176914714419060	Ck1	Bike	1,4188824	-0,49558693	-0,1805601	71	0	true	0	0
Tue Aug 16 14:05:20 CEST 2016	2176914783089900	Ck1	Bike	1,3715485	-0,48438847	-0,19624422	68	0	true	0	0
Tue Aug 16 14:05:20 CEST 2016	2176914852706870	Ck1	Bike	1,3033723	-0,449781	-0,29659647	69	0	true	0	0

Figure 1: Raw data from the VRUMonitor Data Logger. Three log files are created with X, Y, Z values for rotation, linear acceleration and orientation, respectively. The frequency (in Hz) may differ in the three logs depending on the sensors of the smartphone.
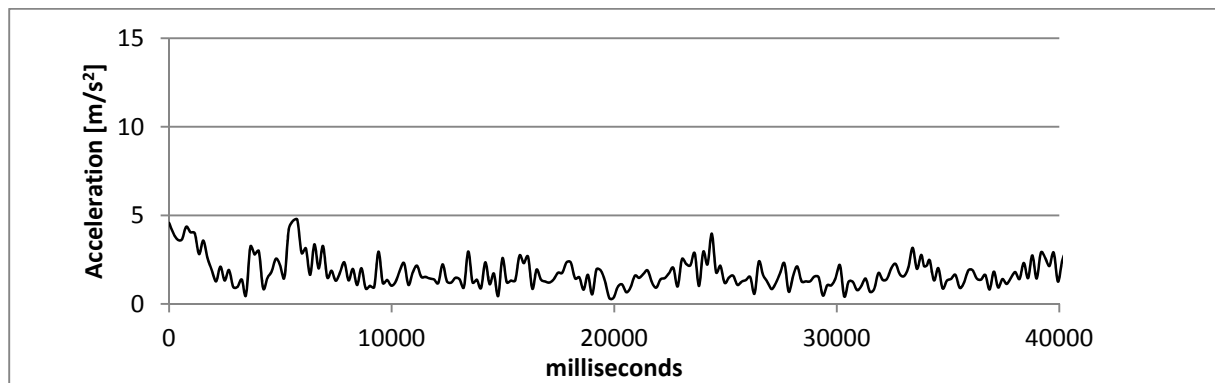
Figure 2: Acceleration (magnitude of x, y, z) [m/s²] from cycling with the phone in the jacket chest pocket.
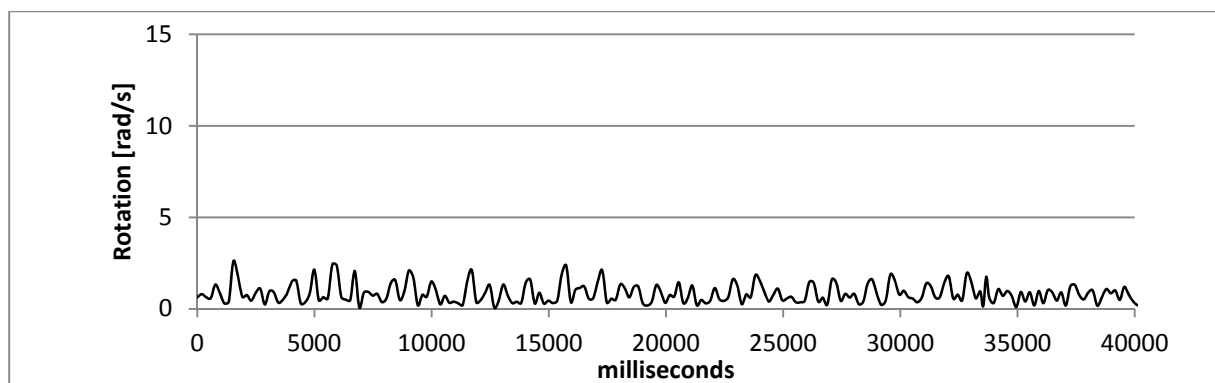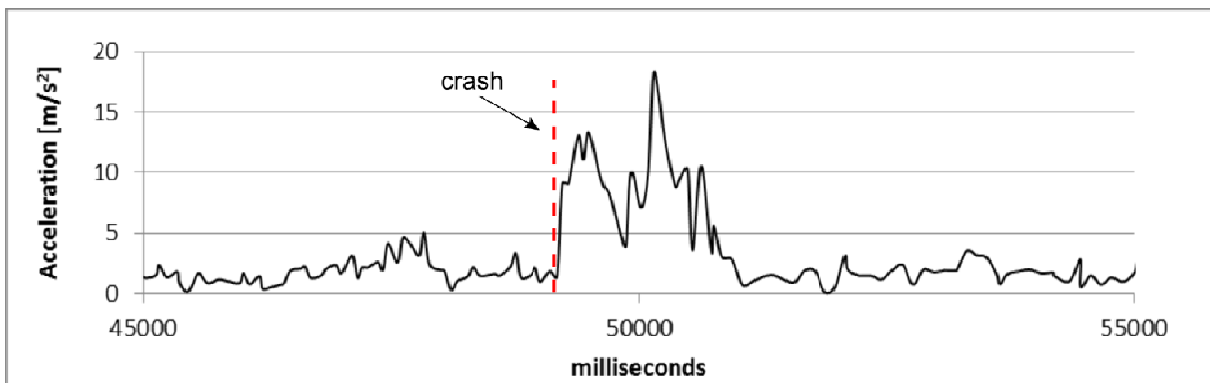

Figure 3: Rotation (magnitude of x, y, z) [rad/s] from cycling with the phone in the jacket chest pocket.

## 3.2. VRUMonitor: Detection of VRU accidents

The VRUMonitor app contains an algorithm for automatic detection of pedestrian and cyclist accidents based on kinematic triggers (acceleration, rotation and jerks) and changes of the state of the screen in order to reduce the amount of false positives from

handling of the smartphone. Once installed, it automatically monitors the movements of the smartphone and uploads data regarding potential accidents to a database. This includes a list of all detected accidents, a list of users having the app installed (phone brand and model), and log files with the time of the measurements, screen state and acceleration and rotation data from 45 seconds before and 45 seconds after the accident was detected. Figure 4 and Figure 5 show an example of the acceleration and rotation magnitudes logged with the VRUMonitor during the simulation of a cycling accident performed by a stuntman.

Appendix 2 provides a further description of the app and the accident detection algorithm, which is based on threshold values. The functionality of the algorithm depends on the frequency of the data collection and thus on the sensors in the smartphone, which differs between different phone brands and models. The algorithm was made based the three smartphones used for testing and data collection: HTC One Mini 2, Samsung Galaxy S6 and Sony Xperia Z5 Compact. Correct functionality on other smartphones with different motion sensors has not been tested.

Figure 4: Acceleration (magnitude of x, y, z) [m/s^2] from sideways cycling fall performed by stuntman with the phone placed in the jacket chest pocket.
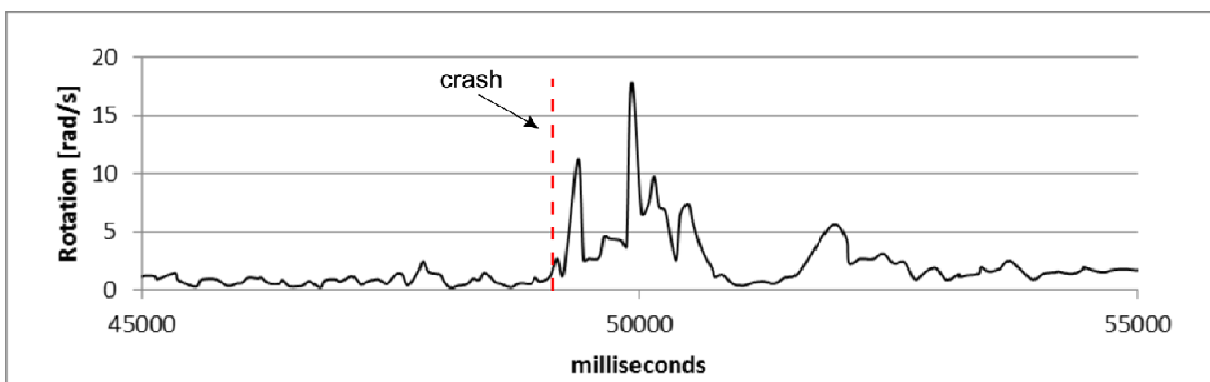
Figure 5: Rotation (magnitude of x, y, z) [rad/s] from sideways cycling fall performed by stuntman with the phone placed in the jacket chest pocket.

3.3. SafeVRU: Questionnaire for detailed information regarding accidents and near-accidents

The SafeVRU app (Figure 6) for Android smartphones can be used to self-reporting of accidents and near-accidents for vulnerable road users (pedestrians, cyclists and moped riders).

When installing the app, users are asked to provide some demographic information: age, gender, zip code, and their email address in order to be able to contact them regarding their participation.

Via a button in the app the user can access the questionnaire, which contains questions about the nature of their accident. These questions concern the time of the accident, their mode of transportation, what happened in the accident, whether other road users were involved and their mode of transportation, weather conditions, road surface conditions as well as questions regarding accident causation factors (e.g. being influenced by alcohol/drugs/medicine, fatigue, distraction). The questionnaire is translated into Danish, Swedish, Flemish and Catalan and was used in the InDeV project to collect self-reported accidents and near-accidents from more than 400 road users in Belgium, Denmark, Spain and Sweden.

Answers of the questionnaire are automatically uploaded to a database, from which they can be exported to a .csv file and further analysed to gain knowledge about traffic safety of vulnerable road users from the reported events. Appendix 3 provides further information regarding the app.
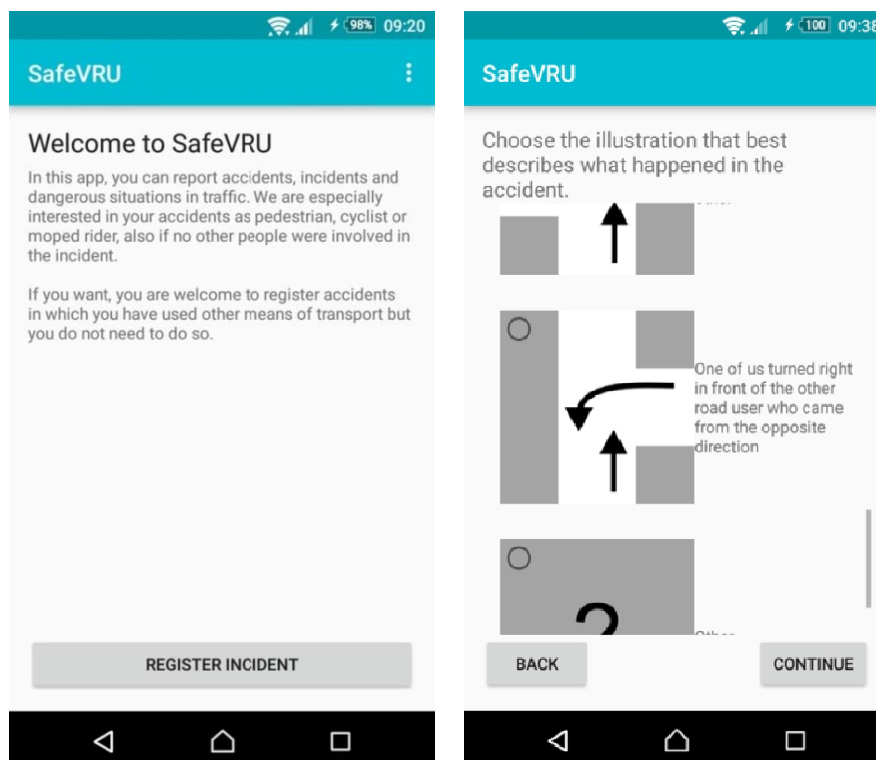

Figure 6: SafeVRU app for self-reporting of accidents and near-accidents. The user can press a button; „register incidents", to report an accident or a near-accident (left). They are then directed to the questionnaire to provide detailed information, e.g. regarding what happened in the accident (right).

4. Conclusions

Three apps for Android smartphones were developed with the scope of facilitating the collection and analysis of naturalistic data and for self-reported accidents or near-accidents from vulnerable road users. In this report, the three apps have been described and the output illustrated. The VRUMonitor Data Logger app can be used for the initial collection of motion data in order to study motion patterns. The VRUMonitor app monitors the motion of the smartphone sensors and analyses the motion in order to detect when an accident occur. In that case, motion data for the instants before, during and after the accident will be uploaded to a database. The SafeVRU app for self-reporting of accidents and near-accidents can be used for collecting detailed information such as where the incident happened and what happened. Within the InDeV project it has been used to collect self-reported accident data form more than 400 users in Denmark, Sweden, Belgium and Spain (Madsen *et al.*, 2018).

Potentially, with the data collected via the apps, one can get insights and knowledge about the safety of pedestrians, cyclists and moped riders. However, further development is needed, partly to be able to clearly distinguish crash events from other movements of the smart phone to eliminate false positive detections, but also to improve the accident detection algorithm so that it can work with sensors with different specifications than those used for the development and reduce the power consumption which on some phones may result in issues with power drain when using the app for monitoring of critical motion.

References

Madsen, T.K.O., Andersen, C.S., Várhelyi, A., Nilsson, M., Oskarsson, M., Jensen, M.B., Bahnsen, C.H., Christensen, M.B., Moeslund, T.B. (2017): *Mobile Application for Naturalistic Walking/Cycling Data Collection*. Deliverable 4.5 of the InDeV - In-Depth understanding of accident causation for vulnerable road users project within the EU's HORIZON 2020 Framework Programme for Research and Innovation. Retrieved from: http://www.indev-project.eu/InDeV/EN/Documents/pdf/walking-cycling.pdf?__blob=publicationFile&v=1

Madsen, T. K. O., Várhelyi, A., Polders, E., Reumers, S., Hosta, P., Bibiloni, D. J., Ramellini, A., Agerholm, N., & Lahrmann, H. (2018). *Assessment of safety of VRUs based on self-reporting of accidents and near-accidents*. Deliverable 3.2 of the InDeV - In-Depth understanding of accident causation for vulnerable road users project within the EU's HORIZON 2020 Framework Programme for Research and Innovation.

Appendices

Appendix 1: VRUMonitor Data Logger

The app (Figure 7) was developed for Android smartphones and was used for collection of preliminary sensor data for development of an algorithm for accident detection from vulnerable road users.

For collection of motion data (rotation, acceleration, phone orientation), write an identifier (1) to include a description of the collected data. Specify the delay (2) before start in order to get the smartphone in place, e.g. in a pocket, and the duration (3) of the data collection. Define the road user type (5) and press "toggle sensor" (8) to start the data collection. The smartphone vibrates when data collection is initiated.

Logs (.txt) of the linear orientation, rotation and orientation are stored in the download folder of the smartphone. Depending on the phone, it may be necessary to use a separate app to access the logs.
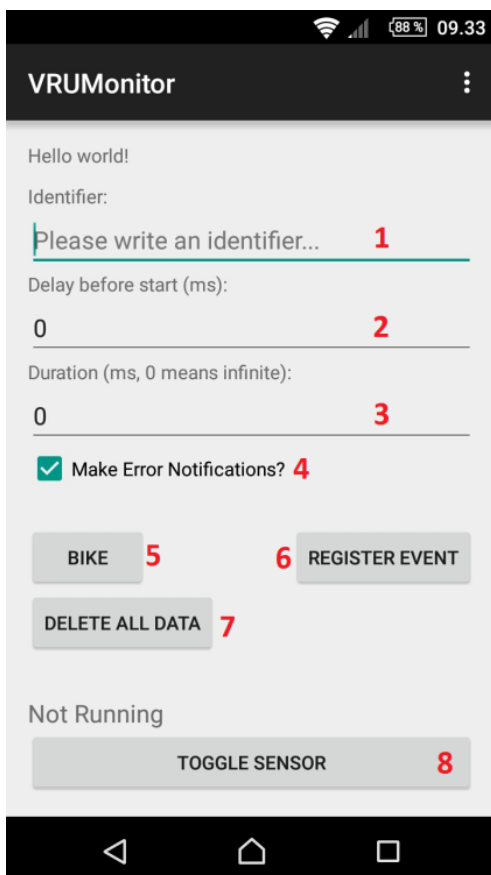
Figure 7: VRUMonitor Data Logger

1: Description of the data that is collected, e.g. "Sony Xperia, cycling to work Monday"

2: Specify how long (in milliseconds) you want to wait from pressing the button to start the data collection until it actually begins collecting data.

3: Specify the duration of the data collection. For instance, if the value is set to 10,000 milliseconds, it automatically stops after 10 seconds.

4: If checked, information will be written to a log in case of errors.

5: Specify the type of road user (Bike, Walk, Other) by pressing the button.

6: Self-reporting of accidents. If you have had an accident during data collection, you can press this button to mark it in the log file. This option is typically not used when collecting data for development purposes.

7: press this button to delete all information in the logs. Do not use this option unless you have either transferred the logs to your computer or that you don't want the data that have been collected.

8: press this button to start and stop the recordings

Appendix 2: VRUMonitor

When the app is installed, it automatically registers movements of the smartphone. Based on this information it assesses whether the road user may have been involved in an accident. In that case, it saves information regarding acceleration and rotation for 45 seconds before and 45 seconds after the accident was detected. Recording of the GPS position at the time of the accident is not implemented in the app.

Figure 8: VRUMonitor accident detection app

To be registered as an accident by the app, the following criteria must be fulfilled:
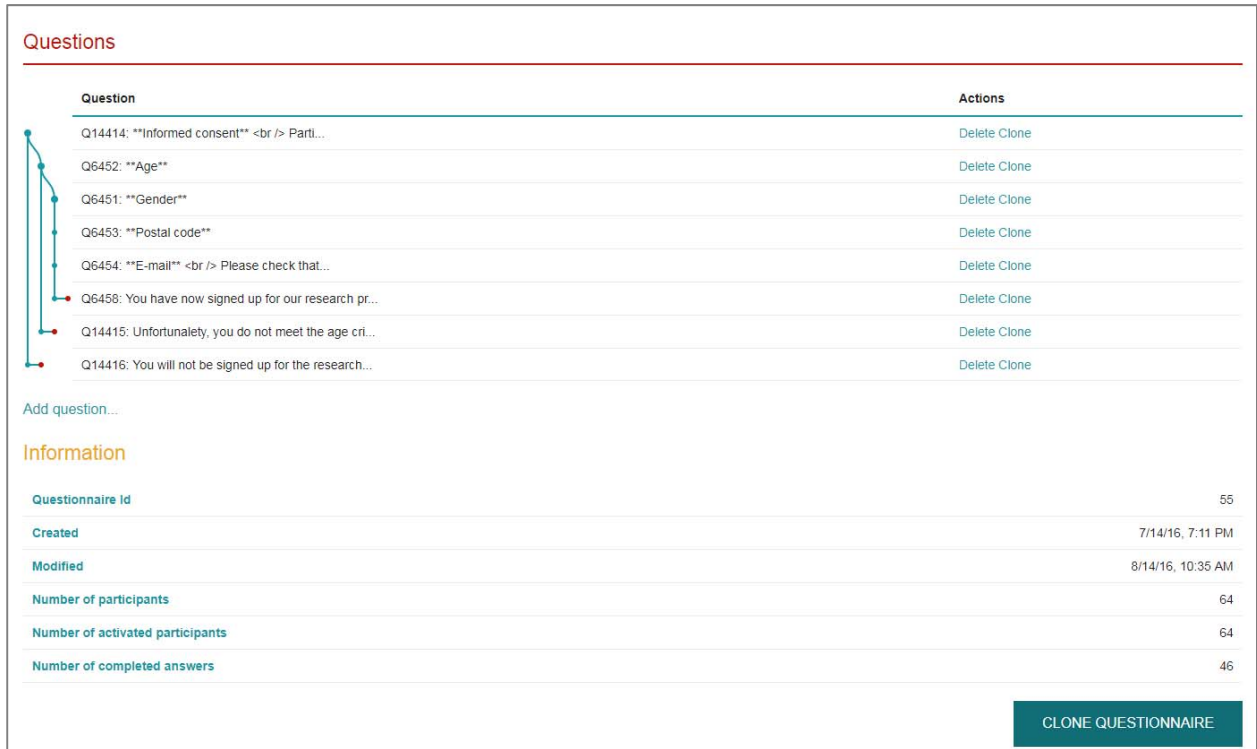
- Total linear acceleration > 8 m/s^2 for at least 4 out of 5 subsequent measurements. Filter: 5-point moving average
- Screen state has not changed within the previous or next 10 seconds

Furthermore, at least one of the following criteria must be fulfilled:

- Jerk > 14.7 m/s^3 for at least 2 out of 5 subsequent measurements. Filter: 3-point moving average. The jerk may occur up to 1 second before or after the acceleration criterion is triggered
- Total rotation > 2 rad/s for at least 4 out of 5 subsequent measurements, Filter: 5-point median. The rotation may occur up to 1 second before or after the acceleration criterion is triggered

Appendix 3: SafeVRU

The SafeVRU app (Figure 10) is made for Android smartphones and is connected to a backend infrastructure (Figure 9) for creation and management of questionnaires and storage of responses, which can be extracted in .csv format for further processing of responses. Source code for the backend infrastructure is available on https://bitbucket.org/aauvap/vrumonitorweb/.

Figure 9: Platform to access the backend infrastructure of the SafeVRU in order to create and manage questionnaires and extract responses of the questionnaires.

Questionnaires can be made with tree-like structures, so that there are different paths through the questionnaire based on the answers to previous questions. The questions can be of different types depending on the desired form of the answer, e.g. text descriptions, single or multiple choices between predefined options, numbers or coordinates to a location on a map. The answer options can be either images or text or a combination of both.
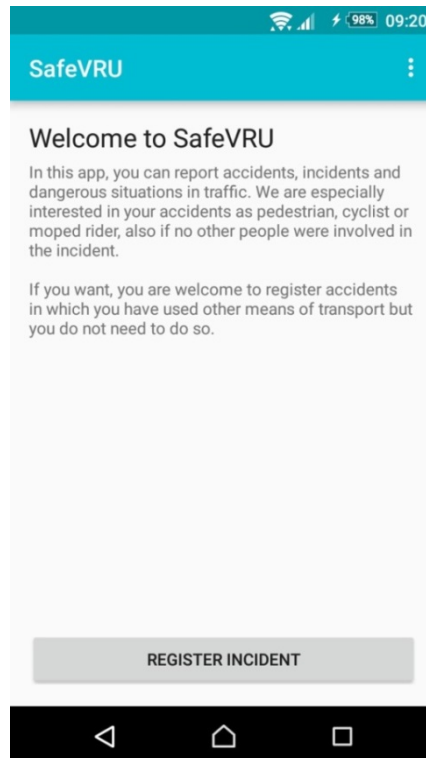
Figure 10: SafeVRU app

In the app, three questionnaires were implemented for a study of self-reporting of accident and near-accidents which was carried out in Belgium, Denmark, Spain and Sweden among more than 400 users.

1. Upon installation, the user provides demographic information (age, gender, zip code) and their email address to have basic information regarding the road users.

2. During the study, the user can change the information provided upon installation, e.g. if moving to another location, by answering a short questionnaire.

3. By pressing the '*Register incident*' button in the app, the user gets access to a questionnaire for registration of detailed information regarding their accident or near-accident: time of the accident, mode of transportation, what happened in the accident, whether other road users were involved and the opposing road user's mode of transportation, weather conditions, road surface conditions, etc.

The SafeVRU app provides a feature to automatically send push notifications each month as a reminder to register any accidents or near-accidents that have occurred. The function, however, did not work on all smartphones, e.g. because the participant had chosen not to receive push notifications.