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## Smart vital signs and accident monitoring system for motorcyclists embedded in helmets and garments for advanced eCall emergency assistance and health analysis monitoring

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### Abstract

The EU funded project i-VITAL investigates an advanced eCall system for motorcycles. Within the consortium three participating SME companies, NZI (helmet manufacturer), Lookwell (garment manufacturer) and CAP (polymer manufacturer) are working together with three research institutes (CETEM, Fraunhofer and TECOS) on a novel vital sign monitoring and accident detection system to be seamlessly integrated into helmets and garments. The project develops and tests sensors to measure vital data of riders in order to enhance the eCall by relevant rider's data. Next to the eCall functionality, i-VITAL also aims at a continuous analysis of real-time vital data to warn the rider in order to prevent possible accidents or health hazards due to fatigue, sleepiness and inattentiveness respectively. To ensure reliability of the sensor system i-VITAL will develop and integrate energy harvesting capabilities into helmets and garments in order to maximize the duty time of the system. The paper presents the i-VITAL approach for eCall enhancement and vital data acquisition and the first project results.

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**Keywords:** eCall; Motorcycle; Health monitoring; Vital data acquisition; Energy harvesting

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## 1. Introduction

Riding a motorbike is a popular leisure activity and important means of commuting in Europe. Motorbikes are less polluting and occupy less space in cities. On the one hand powered-two-wheelers (PTW) have a lot of advantages compared to cars, but on the other hand are a lot more vulnerable when involved in an accident. The percentage of PTW fatalities on European roads has increased over the last years, but considering that 15% of all road fatalities are motorcycle riders, the safety of these road users still requires special attention in research activities [1; 2]. Immediate and adequate emergency response to a motorcyclist having an accident can reduce the number of fatalities. Whereas, eCall is already established for cars, this is an understudied market for motorcycles.

These facts are a motivator for European initiatives aiming on reducing the number of fatalities on European roads and increasing road safety for PTW riders by setting higher standards for vehicle safety, improving emergency and post-injuries services, development of protective clothing and protective devices, as well as the training of road users with focus on motorcyclists [1].

Even if riding a PTW is mostly fun and excitement triggered, safety is an important factor for riders. Furthermore, safety can be the key reason for users in purchasing a motorcycle product and for differentiating between products.

## 2. The i-VITAL project

The i-VITAL project is an EU funded project within the 7th framework program of the European Commission. i-VITAL is aiming on enhancing rider eCall with vital signs data of the riders to overcome the limitations of existing motorcycle eCall systems [3]. eCall is an European level initiative intended to bring rapid assistance to motorists involved in a collision anywhere in the European Union [4]. The i-VITAL eCall message will be compliant with established eCall standards [4; 5], but will go beyond it by providing not only information about the severity of the accident, but also about the health condition of the helmet/garment user. Vital signs information after an accident can be used by medical services in order to prepare an adequate emergency response. The i-VITAL system featuring vital sign monitoring and accident detection will be seamlessly integrated into helmets and garments [3].

### 2.1. Core components

The core of the i-VITAL system is formed by the i-VITAL kits – helmet and garment equipped with bio-signal sensors, and the user's mobile phone equipped with an Android application. All components are linked via Bluetooth Low Energy (BLE).

### 2.2. Enhanced eCall

eCall is activated automatically when i-VITAL sensors detect an accident. Once the eCall is triggered, the system will establish a data and audio connection with the respective service center sending details such as time of incident, accurate position, travel direction, and health data. An eCall can also be triggered manually by using the i-VITAL application. To enhance the eCall with vital sign data, the common MSD content (Minimum set of Data as defined in EN 15722:2011 [5]), especially the optional data block will be adapted and specified accordingly.

### 2.3. Health monitoring, warning and activity feedback

Next to the eCall enhancement, the i-VITAL system will increase the safety of PTW drivers by continuously monitoring the driver's physiological condition while riding. In case a health critical threshold is reached in one or more parameters (e.g. high heart rate, low respiration, fatigue, sleepiness, imminent inattentiveness), a respective warning message can prevent the rider from serious health issues or an accident. Multi modal warnings using audible and haptic feedback considering different urgency levels build the basis for the concept.



Fig. 1. The i-VITAL system.

Table 1. i-VITAL system components [3].

| Component  | Description   |
|--|---|
| Helmet bio-signal sensor module (Kit I)            | will integrate all the sensors and signal conditioning circuits required to capture the vital signals from the user's head. It will also include signal processing to perform accident and impact detection and its severity. As added safety, it will not include any external wire, so that the helmet is completely independent and detached from any other part. All the components will be miniaturized and integrated into the helmet, so that passive safety to impact is not compromised. Its external look has to be as similar as possible to a traditional helmet. |
| Garment bio-signal sensor module (Kit II)          | gathers the sensors, their conditioning electronics and signal processing for monitoring the body bio-signals like ECG (electrocardiogram) and respiration. Additionally, ambient information such as temperature and humidity are tracked at the chest. The garments will be designed so that the different electronic devices can be attached for regular use, and detached for washing. Similar to the helmet case, the integration has to be perfect preserving its external look and hiding the wiring, batteries and other elements.                                    |
| Bluetooth communication modules (in Kit I and II): | both the helmet and the garment subsystems need a Bluetooth communication module in order to communicate with the mobile, which will carry out the emergency call when needed. Data will be stored and processed locally in each module, but if some hazardous event is detected, the relevant data will be sent wirelessly.  |

| Component                              | Description  |
|--|--|
| i-VITAL application (in Kit I and II): | the data sent through the Bluetooth link will be received and processed by an app running in the smartphone. This app will decide whether to trigger the call, then arrange the data and send it. The voice channel will also be opened in case the user can talk to the emergency services and explain the situation. This app can also provide some warnings to the user if some critical situation is detected. The i-VITAL application will be the main system for kit configuration, data analysis and data presentation. Furthermore, it will be the system that will trigger the eCall in case of an automatically detected accident. |

Riding a motorbike in Europe refers often to a leisure activity that is highly associated with fun, thrill and a feeling of freedom. The perceived ‘joy of riding’ depends primarily on the driven route and speed. On this account, i-VITAL will also track activity data and provide information about the rider’s state of arousal in terms of ‘joy of riding’. While health monitoring focuses more on health and safety issues, the vital sign and activity feedback provides a more ‘joy of use’ aspect. Vital sign and activity data will be stored and available to the user after the ride. This functionality of the i-VITAL system is considered as to be the sales argument next to the enhanced eCall.

#### 2.4. Energy harvesting

In wearable technologies, power supply has been traditionally solved with the use of batteries. However, a safety system requires a very high level of reliability. For this reason, i-VITAL will use energy harvesting on the helmet and garment to power its sensors. i-VITAL will create a new harvesting solution that meets the size constraints and energy generation requirements. For Kit I, the helmet, i-VITAL is researching in the field of energy harvesting with wind turbines. Therefore, the helmet will be redesigned to incorporate a wind turbine. In terms of Kit II, solar energy harvesting will be used. On this account, the jacket will be equipped with commercially available solar panels.

### 3. Requirements on health monitoring and vital sign feedback

A user requirements analysis has been conducted to gather the main requirements for the i-VITAL functionalities: advanced eCall, rider health monitoring and warning and the rider activity and vital parameter feedback functionality. Within this requirement analysis a thorough literature review on motorbike driver support systems and state of the art eCall systems has built the basis for the health monitoring and warning use cases and user needs together with stakeholder requirements of the SMEs involved in the project. Similarly, a review on common activity tracking applications from disciplines like running or cycling are the basis for the rider activity and vital parameter feedback application use cases, and user needs. The initial literature findings have then been further discussed in focus groups managed by Fraunhofer. Within the user focus group with novice and experienced motorbike drivers (PTW drivers) the findings regarding health monitoring and rider activity and vital parameter feedback have been discussed and evaluated. Interviews with medical experts have been conducted to identify requirements for vital sign monitoring.

#### 3.1. User requirements

The i-VITAL eCall and vital sign monitoring concept is perceived as safety enhancing. For the vital sign monitoring a benefit for the user has to be made perceptible to have a chance on the market. This would be, for example, the measurement of ‘joy of riding’ by using vital parameters in combination with the tracked route. Automatically triggered eCall is only accepted, if an accident occurs. In all other cases users would prefer to trigger eCall manually by using the i-VITAL smartphone application. Rider warnings are well accepted for constructs like dehydration, fatigue or distraction. But warnings should not be bothering or stressful (users do not want to get warned in case of stress, because this would lead to more stress). For rider warnings different warning/ monitoring profiles should be provided (predefined and created by the user), because users would rather select sets of sensors/ warning scenarios than single sensors. Recorded vital sign data, together with route information should be available locally in the i-VITAL smartphone application, but should also be exportable to other devices. Users would share

'joy of riding' data combined with route information online. But, users would rather connect the i-VITAL application to existing communities than create an account for a new i-VITAL community.

### *3.2. Medical expert requirements*

Interviews with medical experts have been carried out to gather main requirements on vital signs for eCall enhancement. Experts interviewed are accident and emergency doctors as well as ambulance officer.

From a medical experts view main parameters that have to be considered for vital monitoring and enhanced eCall are as follows:

- Heart rate
- Pulse rate
- Respiration
- Blood pressure (implementation in i-VITAL not feasible)
- Consciousness
- Impact on head, stomach and chest (as indication for blunt head or abdominal trauma)
- Preceding vital sign data (e.g. critical health data prior to the accident)
- GPS data for accident location
- Speed before accident (as a term of accident severity)
- Voice connection to the rider

Vital sign measurement helps the ambulance officers and the rescue team to be prepared for the situation. Even if vital signs are measured again when arriving at the accident scene the knowledge of possible injuries provides a focus for the first anamnesis. Additional information like speed or preceding vital sign data may help to estimate the severity of the accident and may prevent the rescue officers from overlooking important medical issues.

An important requirement from medical expert is that the gathered health data should not be transferred as raw data. i-VITAL has to ensure that data provided to service centers and rescue teams is reliable and already processed.

The medical experts also recommended focusing on the comfort and warning aspect of the i-Vital system. Therefore i-VITAL can use the ECG to warn in case of stroke/ cardiac arrhythmias, tachycardia, high stress, fatigue, or in case of hypotension. This could be very important for patients at risk or elderly drivers.

## **4. i-VITAL user interface**

Based on the requirements and the technical specifications the i-VITAL concept for the user interface of the i-VITAL application has been implemented in first prototypes.

Design and UI specification of the i-VITAL application are based on Google Material to create a visual language that is recognizable by the user and therefore supports easy learning of the system.

For the project purpose the i-VITAL application will be based on Android operating system. i-VITAL kits will communicate with the smartphone using Bluetooth Low Energy. Therefore, the application will support only Bluetooth LE devices with a minimum requirement of Android version 4.3 (API 18).

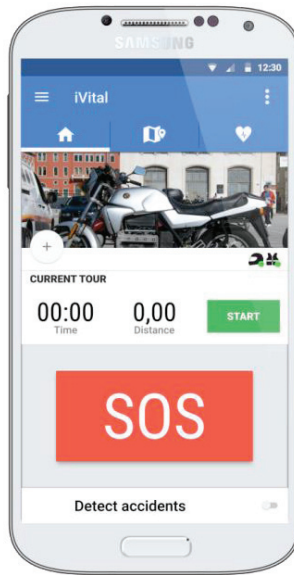


Fig. 2. i-VITAL user interface example.

## 5. Conclusion

i-VITAL describes a novel approach to active safety of PTW riders by developing a health status monitoring system integrated into helmet and garment for accident detection and automated eCall transfer complemented by health data. The concept is well appreciated by the users, because next to safety relevant parameters i-VITAL will provide activity and vital sign feedback. The requirements from user and expert interviews have been implemented into a first hardware and software prototype. In a next step the prototype testing with users will be conducted within the laboratories of Fraunhofer IAO evaluating the i-VITAL concept in detail.

## 6. Exploitation/ commercial launch

i-VITAL is aiming on the development of a market ready system. Therefore, interested partners for participation are welcome. The power of the i-VITAL concept will mature by synergy between supportive strong participating parties. The versatile total concept will boost commercial opportunities for all stake holders, each for its own discipline and motives.

The SME consortium members are aiming to establish participation of an electronics manufacturer. To take interest in funding the industrialization of the product as far as the actual making of the electronic components are concerned. Also, invitation for participation in shape of private or corporate funding is outstanding. Further market parties are sourced for, to distribute the product in wider circles besides the traditional motorbike industry channels.

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