Using wearables to optimise the prehospital medical care management of traffic accident casualties

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Abstract - Road traffic accident represents an important public health issue. One of the strategies to reduce sequelae gravity and mortality is to improve prehospital medical care management. For that purpose, wearable technologies combined with new data processing methods constitute an interesting opportunity. A wearable would indeed enable monitoring quickly the vital signs of a casualty and thus providing an earlier diagnosis, which is beneficial for its outcome. In this study, the technical specifications the wearable device should satisfy for this purpose, and the relevant physiological parameters it should target, are discussed. A wristband solution has been identified among several devices and it will be used to create a post-accident database. Moreover, a new scoring system computable continuously and directly from the wearable is under development. It includes on one hand three intermediate scores representing respectively hemodynamic, respiratory, and neurologic status; and on the other hand a global score calculated from these three intermediate scores. This system will be integrated into a triage interface designed for rescuers.

Keywords: wearable, traffic accidents, vital signs, trauma, scoring system, triage, emergency services

I. INTRODUCTION

Even with the increase in the automobile fleet and traffic, the annual number of deaths in road traffic accidents in France dropped from 18000 in the 70s to 8000 in 2000 and then to 3260 in 2022 [1]. Regarding the number of seriously injured victims, they amounted to 16000 in 2022. Despite the substantial progress, road safety remains a public health issue and this decreasing trend must continue. Besides prevention measures to change users' behaviour and modification of safety legislation to improve road infrastructures and vehicle designs, a key element lies in optimising the prehospital medical care management of traffic accident casualties and of the trauma system organisation.

According to the "golden hour" concept, mortality is affected if medical care is not provided within the first hour after injury. Although this term would date back to the Vietnam war and may be unadapted in a civil context and over-generalised regarding the duration of one hour, it supports the fact that the elapsed time between the accident and the initial care represents a critical prehospital factor for the casualty outcome [2]. A longer medical response time is associated with more severe sequelae and higher mortality [3]–[6]. Reducing the medical response time from 25 to 15 minutes should decrease the probability of death by one-third on average, both on motorways and conventional roads.

To overcome the lack of early information transmitted to the emergency services about the foreseeable injuries, injury mechanisms and associations [7], as well as the feasibility of using accident kinetic data to estimate injuries [8] have been previously investigated. In the context of the boom in the internet of things (IoT), the goal of the present study is to explore the potential of wearable technologies to improve the emergency care system for road traffic accidents. Wearables consist of one or several miniaturised sensors embedded into a garment, an accessory, an implant, an adhesive patch, or even a tattoo. Either electronic, optical, mechanical, or biochemical, these sensors enable to measure user's environment, motion, position or physiological parameters [9]–[11]. They often operate with a wireless communication protocol to send the data on a smartphone or to a distant server for online or offline processing [12]–[14]. Inter alia, these wearables have been adapted for various health applications including diagnosis and biomedical research, remote patient monitoring, vulnerable people (e.g. old, diseased, or elderly); as well as for sports tracking, gaming, and activity or emotion recognition.

Regarding road safety, research about driver drowsiness detection through either wearables or sensors integrated into vehicles is also in progress [15]. However, the present study focuses on post-accident management. It aims to discuss how a wearable would enable to access easily vital signs of the casualties and could be relevant for their diagnosis. In the first section, the specifications such a device should satisfy and the physiological parameters it should target are presented. Several wearable solutions have been considered from lab-built, to research-oriented kits and commercial devices. Then, a new approach for taking advantage of the measured data will be described including elements about a new scoring system computable continuously and directly from the wearable.

II. A WEARABLE TO MONITOR THE CASUALTIES' VITAL SIGNS

Monitoring road traffic accident casualties with a wearable presents several levels of scientific challenges. Over the short term, the device is intended to be installed on the casualty by the emergency workers when they reach the scene of the traffic accident. This characterisation tool would be complementary to the scope monitor with which the French rescue vehicles are already equipped. The wearable would enable the measurement of the casualty's vital signs with minimal handling, for instance before he is moved out of the vehicle. Information about the injured person's state could thus be acquired sooner, which would help diagnose and would benefit the casualty's outcome.

For early prediction of hemodynamic, respiratory, and neurologic distress, and considering the sensors' state of play, the relevant physiological parameters to target are temperature, motion, heart rate, oxygen saturation, and respiration rate. The technologies are already quite mature for temperature [16], and motion that can be measured through inertial measurement units [17], [18]. Several solutions exist for the other parameters. In particular, heart rate is often assessed either by electrocardiography or photo-plethysmography (PPG) [19].

If the wearable is to be installed by emergency workers, it has to fulfil several requirements. A crucial point is that it should be simple and fast to place so that the rescuers can move quickly to the first aid. It should also be non-invasive and compact in order not to interfere with casualty manipulation. For instance, electrocardiography is not adapted because it usually needs several electrodes that have to be precisely positioned. Thus photo-plethysmography should be preferred for heart rate measuring. This can be convenient because oximetry for spO_2 measurement is based on a similar optical measurement principle and both are often combined [20], [21]. In addition, respiratory rate can be extracted from the signal envelope when the signal is good enough [22]. Regarding the wearable format, a wristband seems to be the more adapted because on one hand it corresponds to an easily accessible anatomical site, and on the other side there is no need to undress the casualty or to prepare the skin as for patches. Armband and headband format could also be considered. Power consumption is not a limiting factor since an operating time of a few hours is enough for one casualty's monitoring from the accident to the hospital. The raw data should be automatically saved and the relevant parameters easily displayable.

Several Arduino prototypes have been developed based on lab-built or commercial photo-plethysmography sensors. However, a lot of development would be still required to make the homemade solution usable in this research project. Semi-commercial wearable kits such as from BioSignalPlux were not deemed because they imply the installation of several wired sensors. Among other existing solutions, the E4 wristband by Empatica has finally been selected because the raw data measured are fully accessible, the measurement can be displayed on the dedicated smartphone application E4 realtime, and it has been used for numerous research studies [23]–[26]. This device enables to measure temperature, electro-dermal activity, motion through an accelerometer, photo-plethysmography from which heart rate can be extracted, but no oxygen saturation.

III. Development of a new approach to process the physiological data

Besides identifying the hardware solution that could fit to optimise the prehospital medical care management of traffic accident victims, ways to evaluate the physiological data have also to be thought. Several scoring systems have been developed to assess objectively the severity of a casualty's medical state for different pre-hospital and in-hospital situations [27]–[32]. For instance, the Glasgow Coma Scale (GCS) measures a person's level of consciousness and is especially relevant in the case of head injury; the Abbreviated Injury Score (AIS) and the Injury Severity Score (ISS) focus on anatomical features; the Modified Early Warning Score (MEWS) has been developed to identify patients requiring a higher level of care based on systolic blood pressure (SPS), heart rate, respiratory rate, temperature, and the "Alert, Verbal, Pain, Unresponsive" (AVPU) Score; and the Revised Trauma Score (RTS) is calculated from the GCS, the SPS, and the respiration rate. However medical scoring is still a subject that has to be further investigated. Some studies put their relevance for triage into question [33], [34]. The optimal score seems to be still elucidated [35] and it may depend on the application. Since they need human evaluation, these scores are not calculated automatically, which can be time-consuming depending on the number of casualties to assess and is not adapted for real-time continuous updates. Furthermore, these scores have mostly been used to predict death, without trying to identify the cause.

Our approach is to develop three intermediate scores related to the hemodynamic, respiratory, and neurologic situation, that can be directly computable from the measurements collected with the wearable. The three functions are obviously connected together in real life, but this strategy seeks to be more specific about the injury type and make possible to anticipate the relevant medical resources. The physiological parameters used for the hemodynamic, respiratory, and neurologic scores are given Table I. A global score can also be computed from the three intermediate scores.

TABLE I.

Physiological parameters used for the intermediate scores computation	
Score	***Parameters***
Hemodynamic	Heart rate, PPG amplitude
Respiratory	Respiratory rate, oxygen saturation
Neurologic	Motion, (heart rate variability, electro-dermal activity)

Scoring systems is especially relevant in the case of mass casualty situation like a bus crash, or more broadly in crisis circumstances such as natural disasters or terrorist attack. The simple triage and rapid treatment (START) protocol algorithm aims to sort the casualties into four groups based on four signs: mobility, respiratory rate, pulse rate, and mental state. Each casualty group is associated with a colour code indicating the emergency level for medical care [36]–[38]: green for low priority, orange for delayable, red for urgent, and black for already dead. Alternative algorithms have also been developed [39]. The under-developed scores increase with the gravity and range from 0 to 100. It will be associated to the colour code: green from 0 to 33, orange from 34 to 66, and red from 67 to 100.

IV. Conclusion and Perspectives

Wearables and Information Technology seem to be promising tools to upgrade the prehospital medical care management of traffic accident casualties. A discussion has been carried out regarding the technical specifications a wearable should satisfy to enable the diagnosis by the rescuers without impeding their work. The E4 wristband produced by Empatica has been identified as the best current solution for this specific project. It has been provided to local rescue organisations to constitute a database of physiological parameters measured as soon as possible after the accident, which doesn't exist so far. These data will be processed in order to find predictive features for hemodynamic, respiratory, and neurologic distress.

Furthermore, a new scoring system aiming to overview the hemodynamic, respiratory, and neurologic state of a casualty is being developed. The pre-processing routine, the score functions, and the algorithms based on either standard or fuzzy logic still have to be improved and will be optimised through the constituted database processing. The scores will be associated with a colour code and will be integrated in a triage interface under development. In particular, they will be tested during traffic road accident simulations, as well as firefighter and military exercises.

With the wearables' continuous progress meeting the different challenges of sensors miniaturisation, communication protocols, data processing and storing, power supplies, ergonomics and integration, the technological watch must be continued. Over the long run, with smartwatches democratisation, one could even imagine that people would already be equipped with the wearable and that personalised monitoring could start even before the rescuers reach the accident scene even though such modernisation of the medical emergency system seems a long way off with numerous technical, ethical and societal limitations more or less complicated to overcome.

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