Analyzing stress situations for blind people

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***Abstract* – Detecting stress in the daily life of blind people is a challenging task. In this context, our work focuses on the analysis and detection of stress in the daily life of blind people. In this paper, we present a major step related to data collection in order to detect physiological signs of stress using a network of sensors implemented on a white cane. We present an overview of our system which final objective is to identify the situations that cause stress and predict them in order to assist the blind person with navigation directions along his walking path. The goal of these directions is to anticipate and avoid stress situations.**

Index Terms - Stress analysis, blind people, Accessible, navigation for the blind, data collection, machine learning.

I. INTRODUCTION

We all experience many types of stressful situations in our daily life. Hans SELYE first defined stress as any force that produces abnormalities, pressures or injuries to the human body [1]. John MASON also proved that two types of stress exist: psychological and physiological stresses [1].

Stress can be classified as acute or chronic. While acute stress is the short-term response to a particular challenge or daily activity, chronic stress is a longer-term response to extreme life experiences and challenges [2].

When stressed, the human body replies to stress with a response called General Adaptation Syndrome (GAS). The first step of this response involves the secretion of stress hormones: cortisol and adrenaline [1]. GAS involves three phases:

1. **Alarm reaction,** in which the body takes an immediate reaction called “Fight of Flight”, is a phase that needs a lot of energy to fight or escape and the immune system is subject to infection.
2. **Resistance**, in which body begins to adapt to stress, is a phase where energy is concentrated to stress only that is harmful for health [1].
3. **Exhaustion**, which is the last phase of the GAS in which the body is subject to a long period of stress, body resistance decline, the immune system is ineffective, and the human subject to stress can experience chronic illness and cardiac diseases [1].

In this context, the objective of our work is to detect stressful situations in the daily life of a blind person in order to propose a stress avoidance system

This paper is divided into five sections. In section 2, we present the response of the human body to stress while identifying the physiological signs related to that response. In the next two sections, we respectively present related work concerning stress detection with sighted and blind people. In section 4, we present our approach to detect stress situations in a walking path of a blind person. Finally, some concluding remarks are given in section 5.

II- PHYSIOLOGICAL SIGNS OF STRESS

The sympathetic nervous system (SNS) of the autonomic nervous system (ANS) in the brain, is responsible of triggering the fight or flight response, providing the whole body with sufficient energy to defeat the danger perceived, while the parasympathetic nervous system (PNS) works to maintain a stable functioning of the body. When the danger passes, the PNS triggers the “rest and digest” response that finally calms the body.

After the distress signal is sent by the amygdala to the hypothalamus that activates the SNS by sending signals through the autonomic nerves to the adrenal glands. The adrenal glands respond by ejecting the adrenaline hormone through the whole body. As the adrenaline circulates through the body, multiple physiological changes or physiological signs can be detected [6]:

a) **Energy** will be needed for the fight or flight reaction; it will be transformed or created. The fat stored in the cells will be transformed to glucose for faster need of energy and the liver will produce glucose in a faster way.
b) **Cardiovascular Activities:** Heart rate will increase, high blood pressure, veins will open up to ensure faster return of blood to heart.
c) **Inhalation and Exhalation:** respiration rate increases, breathing deepen up for more oxygen absorption. Lungs, throat, and nostrils open up to breathe in and out at a higher rate.
d) **Senses:** senses become sharpen and toughen, pupils enlarge to make visibility more clear, and endorphins secretion is a trigger to stay focused in case of an injury.
e) **Digestion:** stops through constriction of the blood vessels of the stomach, kidney, intestines and dry mouth.
f) **Skin:** reducing the blood loss as the blood vessels constricts in case of injury, sweat glands open to cool the body down.
g) **Reproduction:** stops, as both productions of estrogen and testosterone decrease.

Main signals related to stress

The two main signals related to stress are the electro dermal activity (EDA) known as the GSR and the heart rate variability (HRV) [7]. GSR is the measure of the skin conductance due to activation of the sweat glands, which are activated by the SNS. A high average value of GSR is directly associated to stress. HRV is the physiological phenomenon of variation in the time interval between heartbeats. It is measured by the variation in the beat-to-beat interval. Generally, a low HRV or less variability in the heartbeats indicates that the body is under stress because of exercise, psychological events, or other internal or external stressors [7].

II- RELATED WORK TO STRESS DETECTION

Hans SELYE first borrowed stress from the field of physics. He defined stress as a non-specific strain on the body caused by irregularities in normal body functions. SELYE pioneered the field of stress and provided arguments that stress affected the health of the human body. SELYE was limited to the physiological view of stress. John Mason conducted an experiment to prove that psychological stress exists, considering two groups of monkeys. The first group of monkey was alone, while the second group was watching the first group getting food. Those that saw others eating had higher stress hormones levels [1].

Literature mainly revealed that there are two main methods to detects or measure stress. The first measurement method is via self-reports and the second through physiological signals resulting of the fight or flight response. The self-report method is a measurement of stress based on the self-report of the human about his symptoms, his feelings, and his acts [8, 9]. On the other hand, physiological signals collection is the most accurate way to detect and measure stress by detecting physiological signals. Below we list some of the methods that use physiological signal measurement to detect stress.

A. *Approaches based on muscle stiffness and touch pressure signals*

Sun et al [10] revealed that stress can be detected based on how a user handles a computer mouse. They explored stress measurements with common computer mouse operations and used a simple model of arm-hand dynamics to capture muscle stiffness during mouse movements. This method showed that the within-subject mouse-derived stress measure is quite strong [10]. In addition, Hernandez et al revealed the existence of stress based on the way a user handles a computer mouse and the pressure of tapping on computer keyboard. 24 participants explored with a pressure-sensitive keyboard and a capacitive mouse, during 30 minutes' session in which they were given tasks consisting of expressive writing, text transcription and mouse clicking. In stressful conditions, more than 79% of the participants showed significantly increased typing pressure and more than 75% showed more contact with the surface of the mouse [11]. On another hand, Gao et al detected stress based on how a human user manipulates and swipes a mobile phone's touch screen. Finger stroke features during gameplay on iPod were extracted and touch power was analysed. Machine learning algorithms were used to discriminate between four emotional states: excited, relaxed, frustrated, and bored. Accuracy reached 69% to 77% for the four emotional states [12]. Moreover, Paredes et al [17] identified stress with just analysing the movement of a car steering wheel. They demonstrated that stress can be expressed through muscle tension in the limbs and measured through the way a person drives a car. As a result, they proved that stress can be detected with only a few turns during driving. Experiments were conducted on 25 participants:13 women and 12 men, with ages ranging from 18 to 67 [7]. Furthermore, Ferdous et al stress' detection method was based on the manipulation and the usage of different types of mobile applications. They explored patterns of usage of the mobile applications and analysed the relation between this patterns and the perceived stress scale. This method was made using a subject-centric behaviour model that could predict stress level based on smart phone application usage. The results showed an average accuracy of 75% and a precision of 85.7% [13].

B. *Approaches based on the measurement of the electro-dermal activity and heart rate variability*

The main approach of Costa et al [14] consisted to detect stress based on HRV measurement and to build a portable device EmotionCheck that can change the user's perception of his heart rate through subtle variations on the wrist. EmotionCheck will give a false feedback of a slow heart rate when the user's heart rate is high. The experiments performed on a set of 67 participants showed that EmotionCheck helps the users regulate their anxiety through the false feedback of a slow heart rate [14].

Macleane et al developed MoodWings which is a wearable butterfly that mirrors the stress of a user in real-time through actuated wing motions. The measurement of stress levels is based on the electro-dermal activity (EDA) and electrocardiography (ECG) signal. Two sensors placed on the sole of the foot collected EDA signal. The butterfly can be held in hand and the motion of its wings is correlated to the EDA signal. The prototype was tested while users were driving. As a result, users drove more safely with MoodWings but experienced higher stress levels (physiologically and self-perceived). Users were enthusiastic about MoodWings and found it useful in several contexts of the experiment [15]. In the same context, Yoon et al developed a monitor patch for human stress detection. It consists of a small skin contact area and with high flexibility to enhance wearing comfort. Skin area minimization was achieved by the multilayer integration of the skin temperature, skin conductance, and a pulse wave sensor.

The skin contact layer making the direct contact with the skin contains the skin temperature sensor and the skin conductance sensor both using aluminium electrodes. The pulse wave-sensing layer contains the pulse wave sensor. For stress characterization, arterial pulse wave signals are required to be transformed in human heart rate variability(HRV) [16]. While Villarejo et al designed a stress sensor detector based on the measurement of GSR and controlled by ZigBee. Experiments were conducted on 16 adults: 8 women and 8 men who completed a series of tests requiring certain degree of effort. Success rate of the experiments was about 76.56 %. The main component of the stress detector is two electrodes. A person's skin acts like a resistance to the passage of the electrical current, since the two electrodes placed on finger will act like they were two terminals for one resistance and thus allow to calculate GSR. The more stressed is the person, the more his hands will sweat. As a consequence, the resistance of his skin will decrease, conductance of the skin will increase, and higher GSR with higher output voltage will be detected by the sensor [17]. Moreover, Egawa et al's approach of detecting stress was based on skin, salivary and facial images parameters measurement. The purpose of the study was to identify potential biomarkers that were not determined in previous studies. The experiments involved 23 Japanese subjects staying for 2 weeks in a confined facility at Tsukuba Space Center. Increases in salivary cortisol were observed after waking up on the 4th and 11th days. Transdermal water loss (TEWL) and sebum content of the skin were higher compared with outside facility on the 4th and 1st days. Increases of IL-1B protein, which is released by cells under infection, could be observed in the stripped stratum corneum on the 14th day and 7 days after leaving and differences in facial expression symmetry on the 11th and 14th days. Salivary cortisol has been found to increase with acute stress. Increases in IL-1B in the stratum corneum and TEWL values indicate degradation of the skin due to stress (inflammatory reaction) [18].

III- STRESS DETECTION FOR BLIND PEOPLE

A. Challenges faced by blind people in daily life

To be legally blind means that someone has a vision that measures 20/200 or less [19]. More often, due to vision loss, blind people rely on others to perform their daily activities. If for some reason they did not achieved to get help from others, they often suspend their activities and stay at home. Thus, due to vision loss, blind people lose their hobbies, leisure and ordinary day life activities. They will be negatively impacted in their life by onset depression, impaired self-esteem, less social active, face many challenges with relations and communications. Blind people face environmental challenges such as outdoor navigation difficulties of unaccustomed spaces. Memory overload of spatial locations of every item or obstacle indoor or outdoor is a heavy encumbrance as well. They face as well social challenges such as the incapacity of participation in social activities and the inability to perform many job functions, which limit the careers options and limit ability to socialize and meet new people. Furthermore, they may face many technological challenges due to inaccessible latest technologies that mostly rely on visual information. Therefore, due to the challenges and the difficulties that blind people face, they are be exposed to multiple stressing situations. In the next section, we present existing studies that focused on the stress detection for blind people.

B. Studies related to stress detection for blind people

The study of Crudden et al [20] has analysed stress caused by navigation and walking in public transportations. Experiments were conducted on visual impaired participants, while rating their stress levels experienced when completing different walking and navigation tasks in public transportation. As a result, they detected higher stress levels when navigating unfamiliar bus routes, walking across urban areas without sidewalks and walking in unfamiliar places. They observed significant predictors of stress in transportation like age, years since vision loss, dog guide use, and physical limitations. Older-age and self-reported physical limitations were associated with higher walking and public transportation stress, more frequent transportation use per month was associated with lower stress levels, dog guide use predicted lower stress level. Participants also indicated activities they avoided due to transportation stress such as entertainment, visiting friends and family [20].

In a study conducted by the Indian Research Institute, students evaluated the challenges faced by visually impaired persons while accessing public transportation buses. A survey was conducted on 16 visually impaired persons and the problems faced when accessing buses. Results showed that 14 participants always needed to ask for help, 11 participants asked for help but received none, 9 participants received misguidance, 5 participants were abused, 14 participants had difficulties in locating doors, and 10 participants confused multiple buses. These results confirm that every visually impaired or blind person misses 3 to 4 buses every day and loses precious time to reach an unintended location. Obviously, the result is that each such person experiences stress and anxiety each time trying to board a bus and may undergo physical injuries when trying to access public transportations [21]. In [23] the goal of the authors was to understand which environmental factors increase stress for blind people in indoor mobility. They developed an approach to detect stress for blind persons during indoor navigation based on the signals of the electroencephalogram (EEG) by the EmotivEpoc+ equipment, the signals of the EDA, and blood volume pulse (BVP) by the Empatica E4 equipment. The indoor navigation route experiment included five distinct environments representable of a variety of indoor mobility challenges. Participants had to enter through automated doors, use an elevator, move across a busy open space, walk down a large spiral staircase, and walk through other obstacles. The route was approximately 200 meters in length and took on average 5 minutes to walk (a range of 4–8 minutes) [23].

C. *Assistive navigation technologies for the blind*

As mentioned in the sections above, the mobility of the blind persons is one of the main challenges faced in the daily life activity. Many tools have been developed to help blind users in the navigation indoor and outdoor. In the following section, we present existing assistive technologies, tools, and studies that assist and help blind users to improve their daily life tasks. The objective of EyeCane [24] is to guide blind people using vibrations and sound effects where the intensity of sound and vibration depend on the proximity of the obstacles detected. Experiments on EyeCane were fulfilled outdoor on blind and blindfolded participants. After only 5 minutes of using EyeCane, both groups have been able to detect obstacles and move along. The success rate was approximately 70%. Other indoor experiments were completed with the same participants. Some of the participants were using the original white cane and others were using EyeCane. Participants using EyeCane hit three walls, while the participants using the original white cane hit 28.2 walls.

UltraCane [26] provides an alternative, which is an assistive technology that allows safe obstacles avoidance and allows navigation around obstacles. It also gives a valuable protection at head and chest height. UltraCane detects street furniture and other obstacles within 2.4 meters. This is obtained by emitting ultrasonic waves from two sensors able to detect obstacles up to 1.5 meters ahead at chest and head height, while giving tactile feedback to the user through two vibrating buttons on the handle placed on the thumb of the user. The two buttons vibrate to indicate the direction of the obstacle and the approximate distance.

In the context of upgrading existing white canes, TomPouce [27] is an electronic case that can be fixed on an original white cane in order to automatically transform it into an intelligent one. It is based on infrared and laser beams pointed to the front. The objective is to detect mobile and static obstacles while indicating the distances.

The following study, Xplor [28] has integrated image-processing capabilities for navigation in the streets. The main goal is the help blind people recognize other people that will cross streets. The prototype is equipped with camera, face recognition software and a GPS sensor. The camera will cover 270 degrees of the facing environment. The face recognition software is connected to a cloud database. Once the camera detects a person's face, the image recognition algorithm will try to match the picture with a name and transmit it to the user via Bluetooth using text to speech technology. A similar approach is LightStick [30] that also integrates image-processing capabilities. It scans for surrounding texts and reads them for the user.

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IV-OUR APPROACH OF STRESS DETECTION FOR BLIND PEOPLE

A. *Stress detection approach*

In the previous sections, we presented the existing studies related to stress detection for sighted users and for blind users. These approaches tackle the challenges faced in the daily life of blind users and tried to determine situations that induce stress. Our main objective is to create a system that detects and predicts all stressing situations, and incorporate them into an accessible navigation system in order to notify the user with all types of obstacles a user may face in his road. Our system is divided into three parts:

1) *Data collection* (see Fig1): In order to detect stressing situations, we need a database of raw sensor data of physiological signs of stress. The sensor data include heart rate variability data, electro-dermal skin activity data, and muscle contraction data extracted from electromyogram sensor. The database also includes obstacles detection and identification associated to specific GPS coordinates. In a later phase, image collection of street details in a specific geographic area is also needed to detect and recognize street objects. The aim of this image collection is to correlate between the obstacle detection and the corresponding objects in the street. Movable and moving objects will not be considered in this phase. In the stress reduction phase, live image processing will take into consideration this type of objects. In this part, we also integrate a self-report analysis in which we aim to detect psychological stress. This self-report analysis serves to annotate the raw data for more precisions in the data analysis phase.

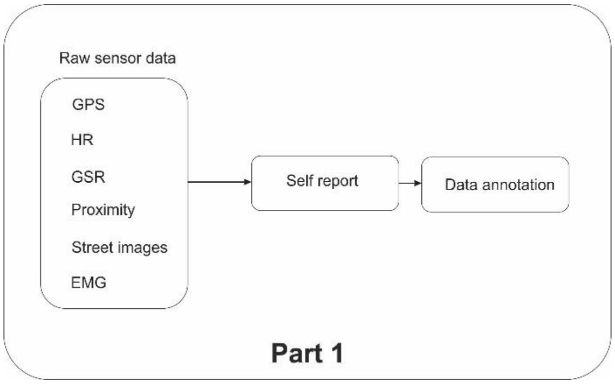

Fig1. Data collection, first part of our stress detection approach.

2) *Data analysis* (see Fig2): Data is collected from users performing daily tasks like walking, using stairs, and navigating in the streets. Collected data serves to detect behavioral patterns and similarities between users in same situations of the street. Supervised machine learning techniques will be used to learn to detect these patterns and build the resultant mathematical model that will detect the stressing situations.

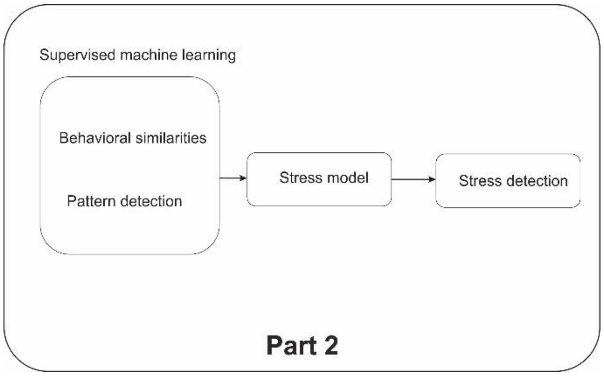

Fig2. Supervised machine learning to detect stressing situations.

3) *Stress reduction* (see Fig3): the objective of this phase is to create a navigation system in which we predict stressing situations in order to avoid them. Once the mathematical model generates all the stressing situations, live data analysis and stress association are integrated in the navigation system. The user will receive notifications in real-time.

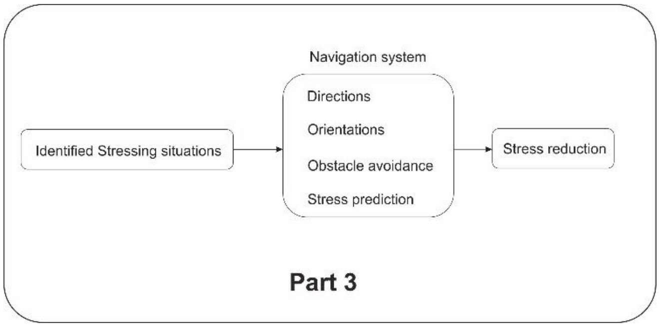

Fig3. Navigation system to reduce stress.

B. *Our prototype for data collection*

In order to collect data, we designed and developed an intelligent interactive prototype called ICane of an intelligent white cane. We integrated on this cane a series of sensors to collect raw data. We also connected this cane to a mobile application for the navigation assistance.

The Figure Fig4 represents our prototype.

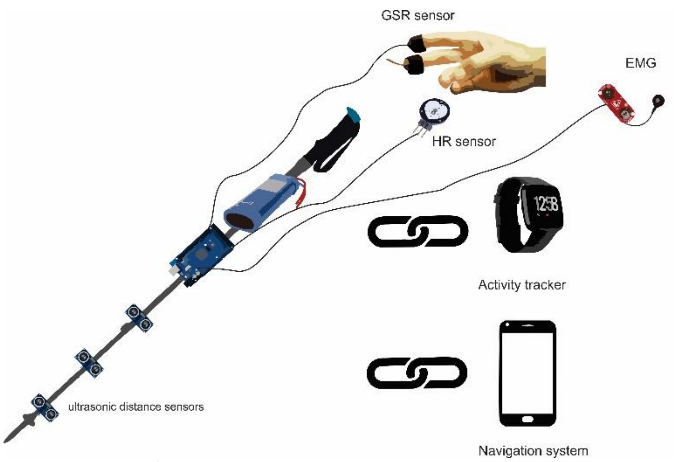

Fig4. Prototype of intelligent white cane.

The white cane consists of the following components:

1) Three ultrasonic distance sensors
   These sensors are positioned at three height level locations. The purpose of this positioning is to detect three types of obstacles. The first type that is considered correspond to low height level obstacles like stairs, walls or any obstacle close to the ground. Medium height level obstacle is considered for suspended objects with no connection to the ground. Finally, the obstacles with higher height level, like windows or other suspended objects, are also taken into consideration with a third sensor. The last two obstacles are not detected by ordinary white canes and are very harmful if not detected. They may be an important source of stress to the blind in his daily life.
2) GSR sensor
   The GSR sensor detects the electro dermal activity of the skin.
3) EMG myoware sensor
   This sensor detects the muscle contractions using the differences in electrical muscle activity.
4) HR pulse sensor
   This sensor detects the heart rate variability.

The cane prototype is associated to the navigation system and the data storage system. The navigation system has the following functionalities:

a) Obstacle avoidance: it provides the blind user with notifications on the three types of obstacles and levels using audio messages and sounds with different frequencies according to the distance to the obstacles.
b) It provides orientations and directions along the path specified by the user.
c) It receives every two seconds the raw data from sensors via Bluetooth and then associates them with GPS coordinates retrieved from the mobile device. Then the data is stored on a cloud database.

Furthermore, data is also collected from an activity tracker that detects the types of activities practiced by the user. In addition, this tracker analyses heart rate to identify if the user is resting, calm or agitated. It also provides raw heart rate data, SPO2 data and resting heart rate for the user. Figure 5 summarizes the complete data collection process.

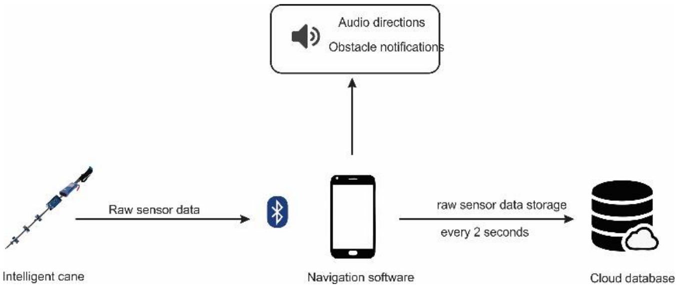

Fig5. Data collection process

C. Data collection experimentation

In order to collect data, we proposed a navigation path to be followed by the users. The aim was to find a frequent and useful route. In our scenario, users had to travel by walk from a residential place to a public building in a city center. In our case, the scenario was implemented in the city of Jezzine, south Lebanon, from a residence situated at approximately 800 meters from the building of the municipality. The city infrastructure is not accessible and not friendly for blind users. Along the path, the person had to deal with different types of obstacles, road forks, mobile and static objects with random car traffic and normal people movement frequency on the road. Figure 6 represents the walking path taken by the users.

Fig6. Walking route scenario of the data collection

The experiment was carried out during daytime in a cool weather. Six blindfolded persons conducted the experiment and they were in a calm, rested situation before the start of the test. Among the six users, two were familiar with the road and the four others were experiencing the path for the first time. Each blindfolded user had to move from the start point to the destination using our prototype. Before each test, the preparation time of the prototype was registered. The duration of the whole test was also registered. The average duration of the walking path of the users was approximately 25 minutes and 12 seconds. The Figure 7. below represents a record in JSON format of the exploitable sensor values extracted.

```
{ "date_user":"26-08-2019 07:27:44
PM","userN":"bouissa" ,"sensordata" : {
    "IR1" : "0",
    "beatvalue" : "54",
    "cm" : "260",
    "conductancevalue" : "218",
    "latitude" : "",
    "longitude" : "",
    "myovalue" : "20"
  }
```

Fig7. Example record of the sensor values

The following graph in the Figure 8, represents the electro-dermal activity of the skin of three users along the navigation path.

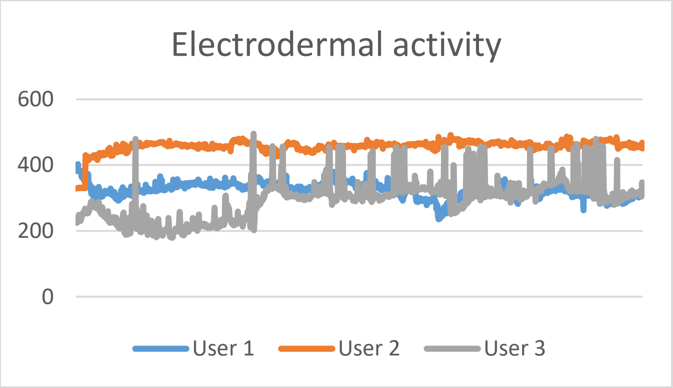

Fig 8. Electro-dermal activity range of three users along the walking path.

This graph shows for each user, a range of electro dermal activity with peaks. These peaks represent sudden change in dermal activity. This change is directly related to stressful situations.

As for the muscle contractions, the Figure 9., represents a graph showing the EMG sensor values. The sensor is positioned in the forearm muscle of the user. When the user presses on the handle of the ICane, the forearm muscle contracts. Consequently, when the user is stressed, he presses more on the handle. When the muscle is relaxed, the value of the sensor is low. In the contrary, when the muscle is contracted the value of the sensor gets higher. In this graph, different peaks of contractions are visible. they may represent sitations where the user faced difficulties in his route.

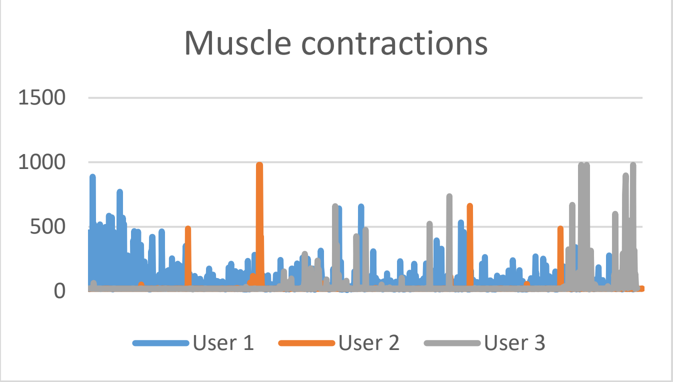

Fig9. Sensor values corresonding to muscle contractions.

As for the heart rate, many characteristics can determine stress situations. According to [29] a resting heart rate for a young adult, ranges from 59 to 99 beats per minute. As for our testers, as they are performing a walking activity, the range of their heart rate is elevated. However, according to [30], Both situations of surprise and stress induce elevated heart rate significantly. In a study they conducted on 8 young to analyze their reaction to an unexpected event. There was a clear tendency between the location of actors (onstage and offstage) and their heart rate in response to stress; the actors present offstage presented immediate elevation in heart the minute the surprising event occurred, but the actors present onstage at the time of the stressor reacted in the following 5-minute period. This tendency regarding stress and heart rate is supported by previous studies; negative stimulus has a prolonged effect on heart rate in individuals who are directly impacted [31]. For these reasons, the Figure 10, presents a prevailing elevated heart rate for all the users with an average of 109 beats per minute. The graph shows as well peaks for surprising situations.

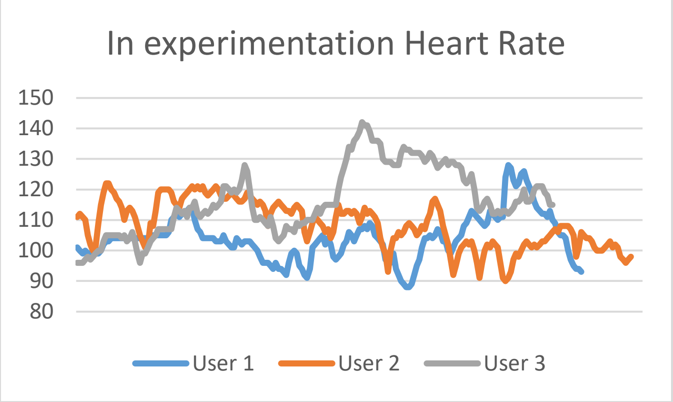

Fig10. Heart rate variability of the users in the experimentation.

V- CONCLUSION

In this paper, we presented a state-of-the-art related to the studies in the field of stress detection for sighted and blind users. The existing studies focused on retrieving the physiological signs of stress and tried to identify the situations that caused stress for the blind people. In the same context, we presented the approach we are currently developing for stress detection using machine learning techniques. In this approach, we need a huge amount of data to analyze it in order to produce a model for stress identification. For this purpose, we developed our own interactive intelligent prototype ICane that serves as an obstacle avoidance cane for the blind users and helps us to collect data for subsequent phases of our project. The final objective of the project is to detect stressing situations in order to mitigate them by providing useful navigations information to blind users of the ICane.

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