Towards Affective Walkability for Healthy Ageing in the Future of the Cities*

Stefania Bandini[1,2][0000−0002−7056−0543] and
Francesca Gasparini[1][0000−0002−6279−6660]

[1] Department of Computer Science, Systems and Communications,
University of Milano - Bicocca, Italy
{stefania.bandini,francesca.gasparini}@unimib.it
[2] RCAST - Research Center for Advanced Science & Technology
The University of Tokyo
bandini@jamology.rcast.u-tokyo.ac.jp

Abstract. Social inclusion of elderly pedestrians in urban contexts by enhancing healthy mobility means increase the level of walkability, where the perception of safe walking and road crossing is a crucial factor. The measurement of stress during walking and dynamic collision avoidance through the acquisition and the analysis of physiological signals during experimental activity requires the design of proper experimental settings and protocols, in order to assess innovative approaches towards an affective walkability, and open novel investigation fields involving affective computing, pedestrian dynamics and artificial intelligence. The main aim of the paper is to illustrate some preliminary studies conducted within an experimental activity to test the validity of the approach.

Keywords: ageing · walkability · collision avoidance · affective state· physiological signals.

1 Introduction

The *healthy ageing* framework 2015-2030 of the World Health Organization (WHO) emphasizes "the need for enabling older people to remain a resource to their families, communities and economies", extending the previous framework from age-friendly cities to age-friendly environment, that comprises physical and social environments in which long-live people live their lives [15].

This framework strongly suggests to create advanced solutions to sustain the social inclusion of the elderly active pedestrians in urban contexts by "enhancing pedestrian mobility" and the level of *walkability* [13], and [6], namely, "the measure of the overall walking and living conditions in an urban area".

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Such approach suggests new perspectives in the design/planning of the future of the cities: how accessible, comfortable, safe and secure the city is for walking/crossing, also in presence of perceptive and motor limitations [12]. Moreover, a healthy and inclusive friendly city is also a city able to develop a “walkable community” [8], namely, to design a human scale environment where safety is promoted, and people can enjoy walking and gathering in comfort [14].

Amid the main factors characterizing walkability (accessibility, comfort, and safety), the concept of *safe walking* is crucial: “walking is a basic and common mode of transport with benefits to health and the environment. Measures must be taken to improve the safety of walkers” [2].

The vehicle-pedestrian interaction while road crossing is a crucial point in the perception of safe walking, and subjective perceptions must be considered, due to the different degrees of vulnerability (age, gender, disabilities) of pedestrians.

In order to focus on the pedestrians’ perception of safe road crossing, new approaches could be investigated, and new sets of technological devices adopted. Wearable sensors and the affecting computing approach [10] nowadays offer new research scenarios, allowing the design of new forms of data collection through pedestrians’ physiological responses during walking and dynamic collision avoidance, being road crossing one of the cases of collision avoidance in the research field of pedestrian behavior modeling and simulation [5], [7]. Measuring and recognizing the affective state of people during walking activities contribute to a better comprehension of their perception of the environment, and a better definition of walkable urban area. The affective recognition task represents a fruitful research direction to the study of *safe walking perception* to assess and introduce quantitative evaluation tools for the measurement of *affective walkability*.

Sensor technology has improved significantly and allows measuring physiological signals as well as registering daily life activities (e.g. inertial sensors, video and audio recordings). Several sensors can be easily integrated into smartphones or wearable devices [17], making them more comfortable and usable. The integration of multi-modal signal sources provides new perspectives towards the creation of an affective walking assessment approach, considering both data coming from physical activity and uncontrolled reactions related to affective responses to stressful conditions. Moreover, the role of Artificial Intelligence when joint to affective computing approaches is more and more contributing to the design of new generations of computer-based system supporting the creation of services for the future cities [16]. The measurement of the level of an affective walkability passes through the measurement of the level of *stress* affecting pedestrians in walking and road crossing, namely, during dynamic collision avoidance. There exist several possible definitions of stress, typically with a negative meaning. Lazarus and Folkman [9], deeply analyzed the concept of stress, especially in its scientific use. They argued that stress, and thus its definition, derives from the observed stimulus-response relationships and neither from the stimulus nor from the response separately. According to them, stress can be considered as intrinsically related to the interaction of the subject with the environment. Within this perspective, and in the context of the research here proposed, it can be seen as a defensive reaction used to protect oneself from dangerous events [11]. Measuring physiological states during walking and collision avoidance through collecting physiological states by means of wearable sensors is the research direction we adopted to grasp more knowledge about, and contribute to design an experimental affective walkability approach to address future application of AI-based learning techniques.

Physiological signals are nowadays widely used to detect affective states [4]. In our investigation we consider Plethysmogram (PPG) and Galvanic Skin Response (GSR) as they are well indicated to detect emotional arousal.

Arousal is a physiological and psychological state that can be related to sensory alertness, mobility, and readiness to respond. It is thus activated in the interaction between pedestrian and the environment as a defensive reaction to preserve safety, which is the connotation of stress here adopted.

Moreover, motion data both physiological, measuring the muscle activity with Electromyogram (EMG), and inertial (accelerometer and gyroscope data) have been adopted, in order to design a novel integrated approach in the study of pedestrian dynamics, within a multi-modal framework.

Relying on different signal sources that register both physiological and dynamic walking responses will provide accurate results for affective state recognition tasks. Within this preliminary research, the multi-modal approach has been adopted, in order to synchronize and properly segment all the raw data streams collected. Depending on the type of signal, a proper noise reduction filtering has been performed. Characteristic patterns of these signals, related to induced stressful states, can be identified and provide new insights for measuring the perception of safe walking.

In this paper, preliminary studies conducted within an experimental activity are described to test the validity of the approach. Section 2 illustrates our study of the perception of safe walking, explaining in details in-vitro (through the design of the experimental setting in a protected space) and in-vivo (data collections in the real world) experiments and observations. Section 2.1 reports our experimental activity on human subjects during collision avoidance tasks, in a strictly controlled indoor environment, while Section 2.2 is related to the evaluation of the perception of safe side walking in a selected urban scenario and experiments considering road crossing tasks (both outdoor). Preliminary analyses of collected data are illustrated in Section 3. Finally, we draw some conclusive remarks about the next steps of the research towards the adoption of the best AI-based learning techniques to be selected to reach an affective walkability approach through massive collection of data (from commercial sensors) supporting the design of future urban inclusive environments.

2 The study of the perception of safe walking

Studying age-driven walking and road crossing behaviors by means of direct observations, two types of experiments have been designed and developed in different environment configurations, conducted respectively in Tokyo (Japan) and in Milan (Italy). These experiments involved two populations: a population of young adults (18 - 35 years old) and a population of elderly people (over 60), in order to compare different affective behaviors.

In Tokyo *in-vitro* data collection experiments (i.e. through the design of the experimental setting in a protected space) have been conducted in a controlled laboratory environment, with the aim of studying pedestrian behaviour avoiding collisions. In Milano *in-vivo* data collection (i.e. data collections in the real world) in an outdoor uncontrolled environment have been carried out, to evaluate the safety perception in pedestrian environments considering in particular crossings, and sidewalks [1].

Both physiological signals and inertial data have been collected using wearable sensors produced by Shimmer[3] [3]. Galvanic Skin Response (GSR), Photoplethysmography (PPG), and Electromiogram (EMG) have been acquired together with accelerometer and gyroscope data. EMG is a two channels signal that measures the muscle activity of the medial gastrocnemius muscle and of the anterior tibial muscle. The adopted sensors are shown in figure 1.

Fig. 1: Wearable devices adopted.

2.1 Dynamic collision avoidance

In order to investigate the walking behavior during a dynamic collision avoidance task, an experiment in a controlled laboratory environment has been carried out. Two different populations have been considered: a population of young adults, composed of 14 Japanese master and PhD students, (22 - 34 years old, 4 women), and Japanese elderly people (retired), 20 subjects, (60-70 years old, 10 women).

[3] https://www.shimmersensing.com/

The controlled experimental environment is depicted in Figure 2. The plan of the indoor environment is reported in the top left image, showing the U path where the subjects are moving. Two subjects (sbj1 and sbj2), start at the same time. The collision avoidance zone is identified by a red rectangle and depicted also in the image at the top right. The two obstacles are controlled by one of the experimenter, and the two subjects have to avoid the collision (bottom right). During the rest of the U path, subjects walk with their own natural pace (bottom left).

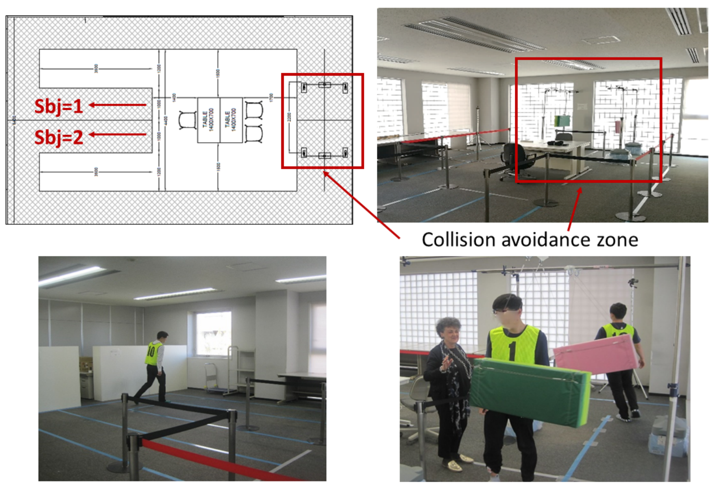

Fig. 2: Setting of the *in-vitro* experiment. Top left: the plant of the indoor controlled environment, where a U path has been defined. The collision avoidance zone is identified by a red rectangle and depicted also in the image at the top right. The two obstacles are controlled by one of the experimenter and the two subjects have to avoid the collision (figure bottom right). During the rest of the U path, subjects walk with their own natural pace.

The experimental procedure is described as follows:

1. **Baseline acquisition**: all data are acquired for one minute, the two subjects standing still. These data serve as reference for each subject.
2. **Collision avoidance**: the two subjects walk with their own pace, till they reach the collision avoidance zone, where they have to avoid the collisions with both obstacles and the other subject. Then they complete the U path, with their natural pace.
3. **Normal walk**: the two subjects walk on the second half of the U path, with their natural pace.

The whole procedure is repeated form 1 to 3, three times.

2.2 Perception of safe walking and road crossing

Fig. 3: The *in-vivo* data collection. The selected urban environment is depicted in the image on the left, where zebra-crossing and sidewalk considered are highlighted with red rectangles. Images on the right report a subject performing the normal walking and the crossing tasks respectively.

For the in-vivo data collection, an experiment in an uncontrolled urban environment has been conducted. For this experiment 14 young adults, all computer science students at the University of Milano-Bicocca, have been recruited, (20-26 years old, 7 women). The aim of this experiment is to evaluate the safe walking perception in urban scenarios, in particular of pedestrians crossings a road, and walking on the sidewalks. To this end, a two way road, in correspondence to a crossroad, without traffic lights, has been considered. In Figure 3 on the left, this experimental environment is depicted. The zebra crossing and the portion of the sidewalks where the experiment was conducted, are highlighted with red rectangles. Images on the right report a subject performing the normal walking and the crossing tasks respectively.

The experimental procedure is described as follows:

1. **Normal walk**: the subject walks on the sidewalks, back and forth, with its own pace.
2. **Baseline acquisition**: all data are acquired for one minute, the two subjects standing still. These data serve as reference for each subject.
3. **Crossing**: the subject has to cross the road in correspondence to the zebra crossing, back and forth.
4. **Baseline acquisition**: all data are acquired for one minute, the two subjects standing still. These data serve as a further reference for each subject.

The whole procedure is repeated form 1 to 4, three times.

3 Discussion

During both the in-vitro and in-vivo experiments, raw data streams from multiple sensors have been acquired. A multi-modal system has been employed to manage all the sensors in order to synchronize and properly segment all the raw data streams into different tasks. As a pre-processing step, preliminary to the segmentation phase, each signal has been filtered to perform noise reduction (see the review paper [10] for details on processing for each type of sensor). Once data has been segmented, due to the high subjectivity of the physiological responses, z-score normalization has been applied. The intent of this work is to reveal if characteristic patterns of these signals can be identified related to induced stressful states, providing new insights for measuring the perception of safe walking.

As an example of what physiological signals can reveal, the *in-vivo* experiment is considered.

In Figure 4, GSR and EMG signals of one subject, collected during the experiment are depicted. Event windows are also drown to highlight the three different tasks of the experiment: B=Baseline acquisition, W=Walk on the sidewalks, C=crossing the street. The Q window (Q=Questionnaires) is the initial part of the experiment when the subject received the informed consent, and all the details about the experimental procedure, and he/she provides personal information (age, level of instructions, gender, etc). The bottom signal (red one) corresponds to the EMG, i.e. muscle activity. As expected, muscles are activated by walking. The stops during the back and forth crossing are also clearly visible. Top signal (blue) is the EDA response. During non-stressful tasks (B and W) the physiological response denotes a low activation, (slowly varying signal), while in correspondence to the crossing tasks (C windows), significant peaks are detectable. Moreover, the two single crossings corresponding to the back and forth paths can be identified by the two main peaks. This preliminary analysis confirms that physiological signals can be adopted to detect an increase of arousal related to induced stress or activated by an attentive state originated by the interaction between subject and environment, especially during collision avoidance tasks.

4 Final remarks

Within this work, the problem of evaluating the perception of safe walking and road crossing (collision avoidance task) has been faced, introducing a novel investigation field, involving affective computing.

An affective walkability approach that relies on physiological signals acquired by means of wearable sensors has been introduced.

The preliminary analyses on data collected in in-vivo and in-vitro experiments show that there are promising correlations between signal patterns and affective states, related to different walking conditions. These considerations justify a massive effort to collect more experimental data from multi-modal sensors

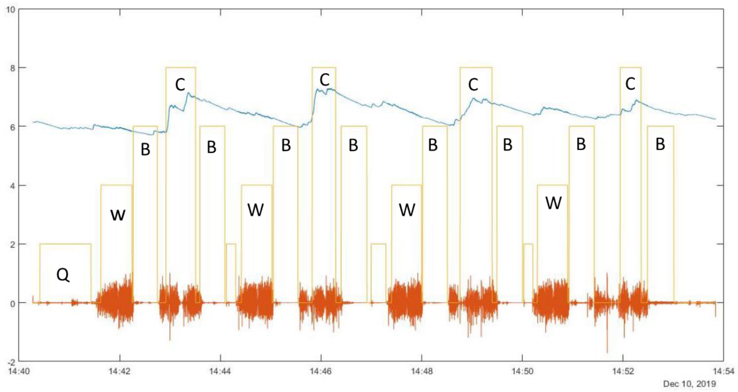

Fig. 4: EMG (bottom, red signal) and GSR (top, blue signal) acquired from one subject in the *in-vivo* experiment are reported. Event window are also shown to distinguish the different tasks: B=Baseline, W=Walk, C=Crossing, and Q=Questionnaire.

within the context of the interaction between pedestrians and environment, especially considering dynamic collision avoidance tasks.

Proper features from all multi-modal signals collected can be extracted. Besides initial statistical inferences that could support our preliminary considerations, to take advantage from multi-modal sources, information fusion is mandatory, either at the feature extraction or at the decision level. Increasing collected data and introducing multi-modal fusion strategies open the direction towards the involvement of AI-based learning perspectives to reach an affective walkability approach in the design of future urban inclusive environments, through the future massive collection of data using commercial sensors.

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