Real-life experiments for walkability assessment in elderly people

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Abstract

Walkability assessment is a quantitative approach to investigate accessibility and confidence in the urban environment for the older people. Physiological responses could be effectively adopted to reveal in particular safety perception while walking in different outdoor scenarios and the definition of a proper experimental protocol is a mandatory step to collect useful data. This paper presents two different experimental protocols for acquisition in outdoor real urban scenarios involving senior citizens. The two experiments face different aspects of walkability in cities, considering both road crossing in stressful conditions, and long walks in urban pathways and parks.

Keywords

Walkability, physiological signals, active ageing

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1. Introduction

In the modern era, active aging is a phenomenon that is worth following, exploiting and studying. Over time, the way of experiencing the city and its spaces will have to be adapted even more to older citizens, that are among those with more difficulties in moving around and in reaching services and common area [1]. A study on elderly pedestrians is therefore necessary to investigate the walkability of difficult areas of the city, such as crossings not regulated by traffic lights where different means of transport come at high speed, and to understand how these elements of stress affect the safety perception of older subjects [2]. Besides more conventional

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self-assessment questionnaires, walkability assessment can rely on physiological responses to evaluate the emotional and affective state of pedestrians during the interaction with urban environments [3]. Physiological responses are nowadays widely adopted having proved their effectiveness and usefulness in the emotion and affect recognition fields [4], [5] as well as in daily activities recognition [6]. In the emotion recognition field, they have been used to understand subject physiological changes with respect to different kind of stimuli, for instance audio [7], video [8], [9] or images [10]. It is thus fundamental to investigate which physiological traits can be adopt to reveal affective state and how these should be manipulated in order to have a clearer and more comprehensive analysis of stress levels of pedestrians [11]. There are several factors that contribute to change the perception of stress in a pedestrian, including age, sex, disability and cognitive impairment. Moreover, other variables deriving from the environment should be considered, such as the presence of loud noises, bulky work vehicles, poor visibility of oncoming cars (e.g. due to cars parked on the side of the road) and lack of signs that facilitate the crossing [12].

The aim of this study is to define proper experimental settings and protocols in real uncontrolled urban environments. These *in-vivo* experiments will permit to analyze the stress levels perceived by older subjects, in dealing with pedestrian areas of the cities where they live, in order to define interventions to increase walkability. To this end two different scenarios in which older people or people with cognitive deficits are particularly exposed will be considered to assess their safety perception while walking: 1) crossing a busy road without the aid of traffic lights, and 2) walking on a long path within the city where both confortable and stressful ways are alternated. For these different dynamics we have designed two real-life experiments, on the territory of the city of Cantù, in Lombardy. The designed experiments take advantage from a pilot one previously performed with young subjects in Milano [2]. This paper describes the multimodal system of sensors adopted, the characteristics of the chosen scenarios and paths, and highlights the critical issues that should be taken into account to perform these experiments. Detailing all these aspects, especially the criticalities that should be solved, this paper stands as a useful tool not only for the reproducibility of the experiments here described, but also as a guideline for other experiments in real uncontrolled urban scenarios.

2. Multi-modal system of sensors

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. We have been encouraged to perform this research, by having obtained positive results in a previous experiment on the pedestrian interaction with younger subjects, whose aim was to collect movement and physiological data as reliable indicators of stress, during safe walking and road crossing [2]. We decide to rely on wearable sensors as the development of the technology makes them more comfortable and usable even in case of older people [6]. In our investigation we consider PhotoPlethysmoGraphy (PPG) that measures the blood volume registered just under the skin, which can be used to calculate the heart rate of the subject, and Galvanic Skin Response

Figure 1: Examples of heavily trafficked roads in the center of Cantù.

(GSR), that measures the skin sweat. Moreover, motion data both physiological, measuring the muscle activity with Electromyography (EMG), and inertial are also collected, in an integrated approach to study pedestrian walkability. The sensors used to collect physiological as well as inertial data are Shimmer3 GSR+ and Shimmer3 EMG/ECG [13]. Both these sensors interface with a software named ConsensysPRO, made by Shimmer as well, used to setup our trials superimposing markers to raw data, and to partially pre-process collected data.

3. Urban scenarios

Searching for the most suitable settings for the walkability assessment experiments, we came across the city of Cantù. Cantù is a Lombard city that has about 40,000 inhabitants and is located at the foot of the Como pre-Alps. The history of Cantù is very ancient and still today its conformation follows that of a medieval town: the streets are narrow, very numerous and often uphill. However, this difficult configuration of the city does not prevent heavy vehicles, buses and a large number of cars from engaging the streets of the city center, which is very busy at rush hour, as illustrated in Figure 1. All these characteristics make Cantù an ideal setting to test stressful routes or crossings for an older person.

3.1. Crossing without traffic lights

An ideal environment for this experiment is configured by i) a heavily trafficked road, ii) the presence of a fairly long crossing and iii) the absence of pedestrian traffic lights. Without becoming dangerous for the subjects who undergo the experiment, the more dangerous the crossing, the greater the emotional arousal triggered and the better the signals acquired. The chosen path is reported in Figure 2 and it is characterized by a large number of vehicles, including work vehicles, and trucks which engage the roundabout all day long and especially in the rush

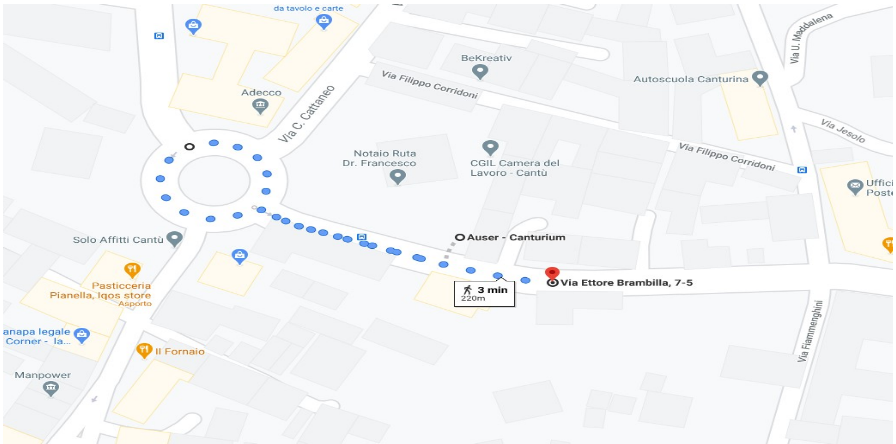

Figure 2: The path selected for the first experiment.

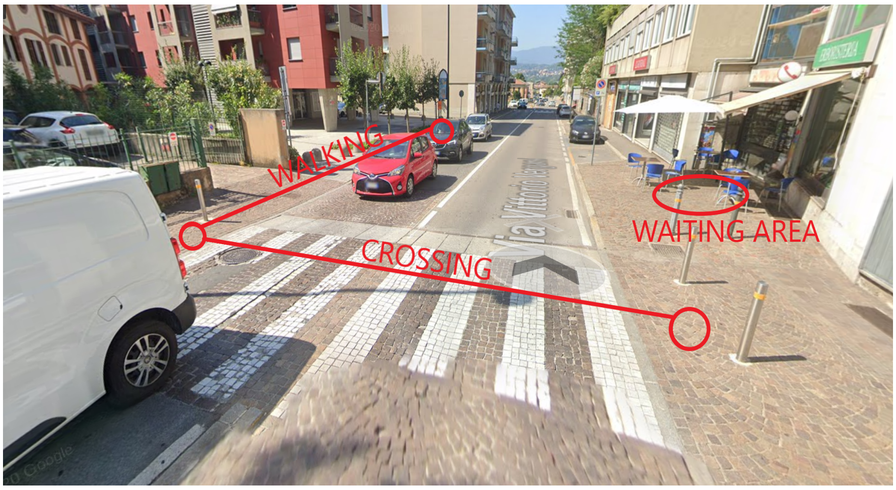

Figure 3: The crossing selected for the first experiment.

hour. We have identified one of the crossings in the roundabout, reported in Figure 3 which has all the features we need: intense traffic, high vehicle speed, a sidewalk for a safe walking task and a comfortable bar where subjects can wait their turn.

3.2. Walking on a long path

The second path that has been chosen represents the best option for carrying out the long walk experiment. In this experiment, which lasts longer than the first one and is devised to test the stress levels on a longer time span, the subject is asked to walk along a path that is initially comfortable, with a consistent ground and, where possible, shaded, without road crossings or dangers of any kind. In the second part of the walk, the subject is asked to continue on uneven ground, on a sidewalk near high-speed roads and where at least two difficult crossings are

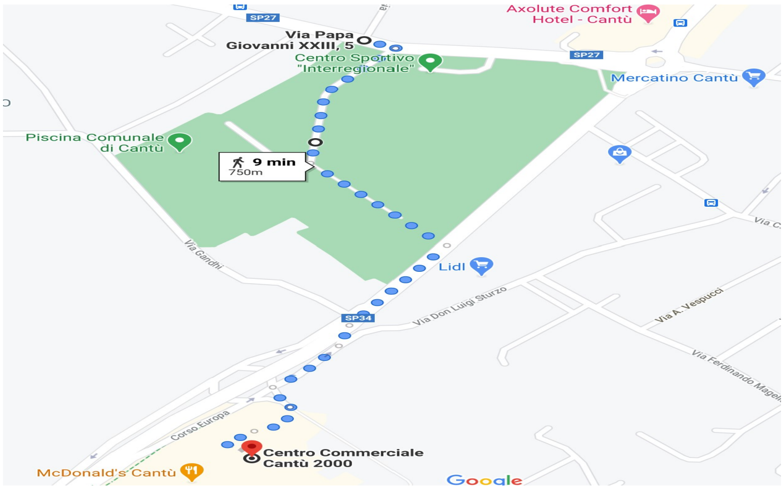

Figure 4: The pathway selected for the second experiment.

encountered. The selected pathway is reported in Figure 4. It begins at the entrance of a park with only pedestrian or bicycle shaded areas, and continues in this way for about 300 meters. Halfway a crossing marks the beginning of the second part of the path: the crossing itself is particularly difficult, as it is quite wide and in correspondence with a sub-urban road where cars arrive at high speed. The pathway continues on a rough sidewalk, next to a busy and also dangerous road, up to the final checkpoint in the parking lot of the Cantù 2000 shopping center.

4. Experimental protocols

For the experiments, two distinct group of subjects are taken into consideration. The first group, with an age between 18 and 35 years and the second group of over 65 years old. The inclusion criteria are:

- (1) age in one of the classes mentioned;
- (2) absence of major medical disorders (neurological disorders, epilepsy, severe cognitive disorders);
- (3) no presence of pharmacotherapy that could interfere with the measured data (psychotropic drugs, anti-depressants);
- (4) no significant visual impairment (all with normal visual acuity or corrected to normal);
- (5) no significant hearing impairment;
- (6) autonomous mobility without the need for supports.

The suitability of the participants will be verified through a self-report questionnaire on personal medical history. Before participating in the study, each individual will be informed by the investigator about the characteristics of the research, both verbally and through an information document. The participant will then be asked to sign for informed consent. Participation in the trial will take place following the voluntary participation of the subjects.

The first experiment considers two different walking scenarios that are supposed to be related to different perception of safety: free walking on a sidewalks, and crossing a two way road in correspondence to a crossroad, without traffic lights. The chosen location is depicted in Figure 2. The sidewalk has been chosen to be wide and comfortable. The chosen crossing, instead, can be considered moderately dangerous for the pedestrians for the following reasons: i) The crosswalk is located on a very busy road; ii) there are no traffic lights to control the traffic flow for both cars and pedestrians; and iii) several different types of vehicles travel along this road especially trucks and motorbikes (see Figure 1 on the left). For this experimentation, the chosen sensors aimed at recording the physiological responses of the participants, are GSR, PPG and EMG. Besides the two walking tasks previously described, the experimental protocol also includes self-assessment questionnaires, for both evaluating the self-esteem levels of the participants and the level of safety perception of each crossing.

The whole protocol is described as follows:

- Baseline: 2 minutes session to acquire the reference physiological signals, where the subject has to stay straight up and still to record his/her physiological responses in absence of any tasks.
- Questionnaire filling: Rosenberg Self-Esteem Scale [14].
- Experiment Core: repeated 4 times
  - Walking on sidewalk (non-stressful task).
  - 60 seconds baseline recording, where the subject has to stay straight up and still to record his/her physiological responses in absence of any tasks, also intended to bring the subject back to a *neutral* state before the next task.
  - Crossing the road and coming back at the start point (stressful task). [1]
  - 60 seconds baseline, same as before.
  - Crossing questionnaire filling.
- End of trial

Within the experiment core, the order of the walking and crossing tasks will be randomly selected for each subject, in order to avoid possible biases introduced by the experimental setting.

The experiment lasts about 20 minutes, being long enough to gather usable data and short enough to prevent the subjects from becoming accustomed to the task at hand. In Figure 5 the

[1] In order to better understand the participant's behaviour, this task is also filmed with a full HD camera. Every participant will properly fill an informed consent to permit the recordings.

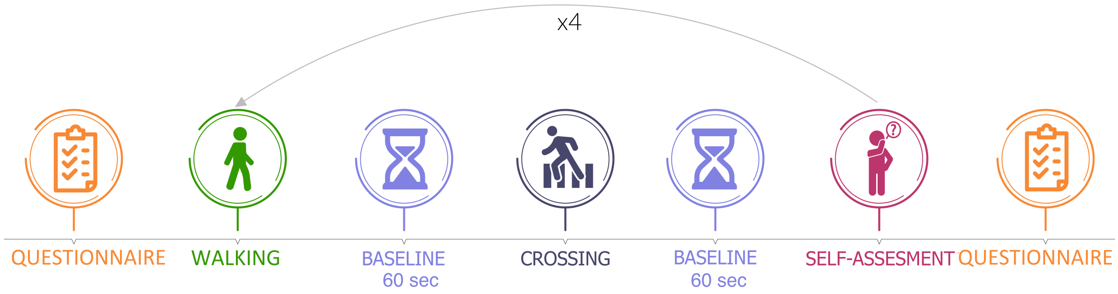

Figure 5: The experimental protocol.

experimental protocol is depicted.

The second experimental protocol concerns the evaluation of walkability along an itinerary that includes both a safe and relaxing walk in a park, and a stressful walk along an sub-urban road, as described in the Section 3.2 and reported in Figure 4. The same physiological sensors of the first experiment are adopted.

The corresponding protocol is described as follows:

- Baseline: 2 minutes session to acquire the reference physiological signals, where the subject has to stay straight up and still to record his/her physiological responses in absence of any tasks.
- Questionnaire filling: Rosenberg Self-Esteem Scale [14].
- 60 seconds baseline recording, where the subject has to stay straight up and still to record his/her physiological responses in absence of any tasks.
- Walking in the park for about 300 meters (non-stressful task).
- 60 seconds baseline recording, same as before, also intended to bring the subject back to a *neutral* state before the next task.
- Crossing the sub-road (stressful task).
- Walking along the sidewalk for bout 300 meters, next to a busy and stressful road, up to the shopping center.
- 60 seconds baseline, same as before.
- Walking questionnaire filling.

The order of the two walking tasks will be randomly selected for each participant. For what concerns the questionnaires, the Rosenberg Self-Esteem measures the appreciation and confidence that a person has towards herself. A Likert scale from 1 (Absolutely not) to 4 (Absolutely yes) is adoped and the items are:

1. I feel that I'm a person of worth, at least on an equal plane with other.

2. I feel that I have a number of good qualities.
3. All in all, I am inclined to feel that I am a failure
4. I am able to do things as well as most other people.
5. I feel I do not have much to be proud of.
6. I take a positive attitude toward myself.
7. On the whole, I am satisfied with myself
8. I wish I could have more respect for myself.
9. I certainly feel useless at times.
10. At times I think I am no good at all.

The two custom questionnaires instead are defined to collect subjective safety perception and are based on a three values scale: NULL, LOW or HIGH. The items of the crossing questionnaire are:

1. Stress level during the crossing.
2. Confidence level towards the cars during the crossing.
3. Interference level brought by other means of transportation during the crossing.
4. Influence level brought by other pedestrians.
5. Confidence level in the crossing without traffic control or traffic lights.
6. Confidence level in the crossing with disturbing elements (parked cars, partially blocked view...)

While the items of the walking questionnaire are:

1. Stress level walking in the park.
2. Stress level while crossing.
3. Confidence level towards the cars during the crossing.
4. Interference level brought by other means of transportation during the crossing.
5. Influence level brought by other pedestrians.
6. Confidence level in the crossing without traffic control or traffic lights.
7. Confidence level in the crossing with disturbing elements
8. Stress level walking along the sub-urban road.

5. Preliminary results on a pilot experiment

A pilot experiment described in [2] has been already performed involving 14 young adults, all computer science students at the University of Milano-Bicocca. The raw signals obtained during the experimentation were pre-processed and cleaned. Proper features reported in Table 1 were evaluated on GSR, PPG and EMG pre-processed signals. In order to correctly compute the features for the GSR, we evaluated the two different components of this signal: the Skin Conductance Level (SCL or phasic part, i.e. all the low frequencies, corresponding to the general trend of the signal), and the Skin Conductance Response (SCR, or tonic part, i.e. all of the high

Features	**GSR**	**PPG**	**EMG**
Max value	X	X	
Mean	X	X	
Variance	X	X	
Mean Peak Height	X	X	
Peaks Area	X		
Peaks Rate	X	X	
Regression Coefficient	X		
IBI		X	
RMSSD		X	
Frequency Mean			X
Absolute Mean Value			X
Root Mean Square			X

Table 1
Features computed for the three types of physiological signals.

frequencies that correspond to the activation peaks). All of the GSR features were calculated from the phasic part of the various GSR signals with the exception of the Regression Coefficient, which was obtained from the tonic part since it contained the necessary information about the signal slope.

Performing statistical Kruskal-Wallis tests comparing feature distributions from different walking activities, demonstrate that those distributions were genuinely diverse, corroborating the hypothesis that physiological signals can be adopted to perform walkability assessment.

Moreover experiments in a laboratory controlled environment considering both young adults and older people have been already performed with the aim of discriminating affective states of subjects during different walking tasks. These experimnets confirm that physiological signals can discriminate among different affective states and that they are also suitable for both the two considered populations [15].

6. Critical Issues

As the proposed experiments will be performed outdoor in real life scenarios, several issues should be considered and problems solved that are not present in a controlled in-vitro experiment and that came from the experience of the pilot study. The main issues can be listed as follows:

- **Temperature / Wind**: Low temperatures affect the correct data acquisitions for two main reasons: 1) subject can suffer during baseline acquisition (in which the subject must stand still); 2) the measurements made with the GSR sensor are less precise, because this sensor has pre-set temperatures at which it processes the signals optimally, between 20 ° and 25 ° C. The wind, on the other hand, could create problems especially with the EMG sensor: the electrodes, in fact, which stick to the skin with a conductive gel, are not particularly adherent and in the presence of wind undergo the micro movements of the hairs rubbing on the skin, losing the contact. To favor the correct acquisition of physiological signals, the data acquisition should be carried out in the mildest months of the year, avoiding the coldest and also the hottest ones that affect sweating or heart rate measurements.

- **Signal loss**: sometimes caused by too much data not supported by the bluetooth protocol. The streaming of the acquired data should be monitored continuously to verify the correct data acquisition. Distance from the PC should be kept under 25 meters to prevent the connection from being lost.
- **Computer battery**: Communicating live with two devices through the proprietary software Consensys is burdensome for the battery of the laptops. This circumstance makes long-term outdoor acquisition campaigns difficult.
- **Missing Event Markers**: while using the SD within the sensors instead of transmitting data via blutooth to the PC, markers to label events are not allowed. The use of the SD is mandatory acquiring data in the second experiment, as the subjects travel long distances. This makes it necessary to find another synchronized marker modality.

Conclusion

Two experimental protocols to investigate safety perception of older people have been presented, supported by preliminary results on a pilot study. Two real life urban scenarios have been already identified. However, the same protocols will be replicated in other cities, involving both elderly and adults to permit more comparison and collect more data. The results of the analysis of these data will be corroborated by the results obtained in in-vitro experiments already performed as well as still running on walkability assessment in a controlled laboratory environment. These analyses are in accordance with the results of other studies [16], [17], where sensors aiming at collecting physiological data are integrated respectively in a prototype cane and in an insole, to support people while walking in different scenarios. Sensors are becoming more and more usable both in their reliability and in the possibility of being smart accessories: in a non-distant future they are supposed to be easy to wear and carry around on a daily basis. Therefore they will have a bigger part in favouring the active participation to social life of people with reduced mobility or disabilities supporting their autonomy and independence.

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