HeritACT The project has received funding from
HORIZON-CL2-2022-HERITAGE-01
under Grant Agreement Number 101094998

heritact

USER SENCE

User Manual

Index

Summary

This document presents the tool to explain in depth its function and application procedures, as Usersence is a user experience evaluation tool that integrates an interdisciplinary approach for its implementation combining fields such as User Experience Deisgn and and Data Science. This document seeks to outline the theoretical background of the tool's design and function and contributes to the understanding of its importance. Therefore, in order to illustrate the essential components necessary to explain the tool's structure, it is imperative to present the following five main sections, a)User Experience, b)Emotions, c)Biosensors and Self-Report Methods. Moreover, the User Manual provides information about the tool design, to help the reader understand the overall framework and the role of the tool, by presenting its software and recommend hardware. Furthermore guides the reader through the process, in order to generate the experience chart, that communicates valuable and meaningful insights into the multifaceted aspects of the User Experience. In the following chapters the reader will uncover the steps in order to integrate the Usersence tool into an evaluation process. More specifically an evaluator will learn:

- What is the Usersence tool.
- What device setup tp use depending on the evaluation location.
- How to organize the exported files, originating from the wearable and mobile devices in combination with certain sotfwares.
- How to process the record data through the Command Link Application.
- How to generate the Expierience Chart.

Introduction

User Experience

User experience design offers a unique perspective on the creation, interpretation, and evaluation of an activity, as it breaks free from the restrictive framework of usability by including more variables related to the observations, emotions, and perceptions of the participants that influence the core concept of an experience (Albert & Tullis, 2022). Although the definition of the term: "User Experience" can be expressed in a variety of ways depending on the context and circumstances, it is important to highlight two key definitions to understand the term and its contribution to the tool's configuration.

Firstly, according to the International Organization for Standardization (ISO), User Experience (UX) is the way someone thinks, feels, and reacts to the use or the expected use of a product, system, or service. Moreover, ISO clarifies that UX includes a plethora of aspects related to the experience such as the user's opinions, conceptions, ideas, assumptions, physical and psychological responses, achievements, actions, and behaviors that arise at any time prior to, throughout, and following the use and interaction. Also, ISO highlights that UX is the outcome of the interactive system’s components (presentation, interface, capabilities, efficiency, and supportive options of the interactive system) and of the user’s state that has been shaped through time (abilities, beliefs, personality traits) and their interaction within a specific context. Last, but not least, ISO mentions that usability is able to contribute to the evaluation of user experience because it can be perceived as metrics that describe aspects of user experience related to the goals or motives of the users (ISO, 2010).

Secondly, Don Norman and Jakob Nielsen argued that UX: *"encompasses all aspects of the end-user's interaction with the company, its services, and its products."* claiming that offering services and conducting the required processes to meet users' needs will contribute to the fulfillment of their goals and objectives, leading to an adequate user experience. Of course, Don Norman and Jakob Nielsen explain that the quality of UX may be affected by a variety of factors (engineering, marketing, graphical and industrial design, and interface design) and they also emphasize the differentiation between UX and usability, as the former is a broader concept, while the latter can measure the qualitative user interface features (e.g. efficiency, ease of use, learnability) (Experience).

The above-mentioned definitions underscore the importance of designing a tool that offers the possibility of capturing different aspects of the User Experience during a time-limited session, as they reveal the complexity of its constituent elements. Naturally, capturing all these aspects with a single tool is so far unrealistic, as opposed to creating a tool that can measure specific and well-defined data. In this way, some crucial questions arise regarding the type of collected data and their recording methods, and thus it is essential to define the concept of the User Experience metrics. These metrics provide insights into the experience itself, describing how the user, usually referred to as a participant, perceives the use of a product, system, or service. A UX metric depicts a finding about the user's interaction with a product that is being evaluated, disclosing information about people's behavior, attitude, or perspective. It is pertinent to note that each UX evaluation differs in terms of the research objectives and the users' goals, the technology available and accessible to collect, analyze, and present the data, and the time and expertise required for the appropriate processing of the findings. Therefore, it is impossible to establish precise metrics that should be employed in every case of a UX evaluation (Albert & Tullis, 2022).

Defining the evaluation objectives can initially determine the metrics by specifying how the data will be used in formative or summative evaluation. When the evaluator seeks to make improvements to the system before its official release, then they conduct a formative evaluation, because it is an iterative process in which observations and comments are being gathered to modify the design features of a system. After each new change, a formative evaluation is conducted again until the design is considered complete. Hence it is evident that the more formative evaluations conducted, the greater their impact on the final design. In contrast, a summative evaluation is carried out when its goal is to measure how well the system, or parts of it, meets its design objectives. More specifically, this type of evaluation focuses on whether the system achieved its objectives, how it shaped the user experience, how it differs from other competing systems, and finally, how it differs from a previous version of the system, if any (Albert & Tullis, 2022).

Meanwhile, in order to understand the users, as well as their interaction with the system, evaluators should focus on three key aspects of the user experience which are performance, preferences, and emotions. Firstly, performance is related to the user's actions during system interaction. Its metrics are measurements of the success of a task or of a series of tasks and the time that is required to complete them, the user's effort that is needed to perform the task, the errors and their frequency of occurrence, as well as the time to get familiar with the system. Secondly, users may have preferences, for example, regarding the aesthetics or the visual identity of the system, the functionality or the hierarchy of certain features, and the practical worth of the design in general. Of course, these preferences indicate the users' attitude toward the system, and the evaluator should consider whether these preferences affect the user experience to such an extent that either radical or minor changes are needed, or the system can be considered successfully designed. Finally, the influence of emotions on user experience is a primary aspect that evaluators seek to research, due to the fact that in the present day more and more products, systems, or services aim to offer holistic experiences. Consequently, systems aim to establish a deeper connection with their users, strengthening the level of trust and confidence, engagement, or the positive emotions associated with them (Albert & Tullis, 2022).

In conclusion, it is evident that according to evaluation objectives, the system, and the users, in other words, the circumstances, the environment, and the context of use, there are different UX metrics and data collection techniques. The Usersence tool intends to evaluate the emotional aspect of the user experience, in products, systems, or services that have officially completed their design process and are available to the public. Thus, the tool should be utilized during a summative evaluation, using appropriate metrics that can depict the user's emotional state by quantifying their feelings. Of course, the tool could be used in a formative evaluation during the early design phases, only if the design team decides that the Usersence covers their research objectives, requirements, and needs. Additionally, measuring user emotions varies on the UX context, and for this reason, it is requisite to present a summary of methods and practices that contribute to the users' emotion estimation and to specify the aspects of the UX that the tool will be able to interpret.

Emotions

Measuring the user experience and more specifically the participants' emotional states is a particularly complex and difficult process, due to the broad spectrum of human emotions and its challenge to accurately capture (Albert & Tullis, 2022). The Usersence tool aims to integrate certain methods, practices, and technological equipment to offer a holistic approach to evaluators who seek to conduct formative or summative evaluations focused on recording and analyzing the emotional UX of a product, system, or service. In order to achieve the design and development of the tool, it is crucial to highlight the importance of the fundamental methods involved in the evaluation as well as the emotions that can be analyzed in the UX context.

Firstly the primary evaluation methods are based on observation, psychophysiological measures, and questionnaires (self-report practices) (Maia & Furtado, 2016). Biometric data of a person, contribute to the recording of the psychophysiological measures, as they offer the ability to approximately confirm the intermediate emotional states of the user (Jain et al., 2011). The recognition of emotional states is supported by the utilization of wearable devices that can capture various data. However, it's important to highlight that they face certain challenges and problems related to the quality of the data and their processing techniques (Saganowski et al., 2020). Nevertheless, wearable and mobile devices have been used to monitor the users' body responses during their interaction with a system. Biosensors provide physiological data such as neural activity, heart rate variability, and skin conductance, offering valuable evidence of users' mood states in the evaluation (Malhi et al., 2017). Emotion recognition through biological signals originating from wearable devices is an intricate procedure, and thus the emotional model on which the recognition will be based must be determined. The selected model will specify the emotion categories of recognition affecting the outcomes of the research. In addition, the recognition varies depending on the location (laboratory or field) where the evaluation is conducted. In the laboratory, a researcher is able to cause emotional fluctuations in participants' emotional states, due to the usage of pre-scripted and pre-planned stimuli, while in the field, a more unpredictable environment, questionnaires can be used to record information during the physiological data monitoring (Saganowski et al., 2020).

Furthermore considering emotions as states that affect a person's behavior and cognitive reactions, as a result of internal or/and external stimuli, a two-dimensional model has been established by Russell (Russell, 1980). This model separates emotions based on two characteristics, arousal and valence as they can depict each affective state. Arousal provides information about the level of a user's involvement in response to stimuli, for example, anger produces an extreme fluctuation in an individual's physiological response compared with a more subtle or mild response like boredom. Valence determines whether the emotion is positive or negative, indicating that higher measurements of valence correspond to more pleasant situations, while lower measurements correlate with disagreeable ones, such as stress, anxiety, or irritation (Cittadini et al., 2023). To sum up, Russell's emotional model established a framework illustrating emotions with dimensional models based on observable and measurable physiological responses as a result of valence (pleasure-displeasure) and arousal (activated-sleepy) values. Lastly, the model introduced emotions as a whole consisting of *"loosely coupled components"* that shape the experience and expression of affective states and include physiological responses (for example fluctuations in heart rate or electrodermal activity), bodily expressions (such as facial expressions or body language), and appraisals (cognitive assessments and interpretations of conditions) (Calvo & D'Mello, 2010).

More specifically, the fluctuations of physiological signals are related to the involuntary changes in emotional states that usually are not perceivable by the individuals. Therefore, biosensors are a reliable method of recognizing emotions because they monitor different parts of the human body. For instance, through photoplethysmography (PPG), the activity of the autonomic nervous system (ANS), the galvanic skin response (GSR), and the blood volume pressure (BVP) can be monitored. Also, another benefit of biosignals is the insertion of their sensors into wearable and mobile devices, allowing non-intrusive user-system interaction monitoring. Such equipment is used in User Experience evaluation and other fields such as medicine, healthcare, education, games, and sports (Domínguez-Jiménez et al., 2020).

Additionally, according to William Albert and Thomas S. Tullis (2022)], in User Experience seven affective states often play a pivotal role, engagement, trust, stress, joy, frustration, confidence, and surprise. Firstly, they define engagement as the level of involvement or interest between the user and the system, associating engagement with arousal (the higher the engagement, the greater the arousal, its opposite state is boredom). Of course, they outline that engagement can correspond with any emotion like stress, surprise, or frustration and thus is important to measure engagement while taking into consideration other emotions that may contribute to the arousal's value changes. Secondly, the researchers describe trust as the relationship between the user and the system, that is being established while the system is offering all the required information even if it is not beneficial for itself. Also, the pressure or emotional strain resulting from demanding circumstances during system interaction is related to stress, which varies based on individual perception. In UX, joy is the affective state when the user is completing a task without difficulty or effort (low cognitive load) and thus its opposite state is disappointment or frustration (high cognitive load), which is associated with the user's struggle to achieve a goal or fulfill a task. Moreover, confidence is illustrated as the user's firm conviction of understanding their actions and avoiding any unnecessary actions with certainty. Finally, surprise, which may be positive or negative thus its connection with valence, is the feeling of unpredicted events that occur during system interaction.

However, William Albert and Thomas S. Tullis highlighted that other emotions might contribute to the UX evaluation contingent upon the system and use-case scenario and that each emotion corresponds to different data collection practices. Usersence tool seeks to measure engagement, stress, joy, and frustration based on biometric and self-report data, due to the recommendation of William Albert and Thomas S. Tullis to combine data collection methods. These methods have significant implications for the tool's design and structure and thus the next chapter focuses on the biosensors, as well as the self-report practices that the Usersence will utilize to provide reliable insights for the UX evaluation.

Biosignals and Self-Report Methods

In User Experience, emotions can be observed with a variety of different methods utilizing advanced equipment to achieve reliable data collection. Researchers in the field have argued that Facial Expressions, and more importantly physiological signals provide the opportunity to capture the unprompted user's reaction. Electroencephalography (EEG), Electrocardiograms (ECG), Galvanic Skin Response (GSR), Muscle Activity or Electromyogram (EMG), Skin Temperature (SKT), Blood Volume Pulse (BVP), and Respiratory Volume (RESP), are physiological signals that are used for emotion recognition in combination with other methods, such as self-report questionnaires, to ensure optimal outcomes (Wiem & Lachiri, 2017). A comprehensive review of the literature ((Doma & Pirouz, 2020), (Bota et al., 2019)], (Schmidt et al., 2019), (J. Zhang et al., 2020), (Egger et al., 2019)) reveals that users' affective state detection is a complex procedure. Thus signals' combination selection is required as using the available methods all at once, is particularly time-consuming, expensive, and not suggested. To achieve its multimodal approach, the Usersence tool utilizes three primary biosignals, Galvanic Skin Response (GSR), Blood Volume Pulse (BVP), Electroencephalography (EEG), Facial Expressions, Questionnaires (self-report practices) as well as user location (GPS) and video footage of the user's perspective. In the following paragraphs, a brief overview of each method will be presented, to highlight their contribution to the Usersece tool. In the following paragraphs, a brief overview of each biosignal or UX measuring method will be presented, to highlight their role in the Usersece tool.

Galvanic Skin Response (GSR), also referred to as Electrodermal Activity (EDA) or Skin Conductance (SC), is the changes in the sympathetic part of the human autonomic nervous system, expressed as the electrical conductivity of the skin due to stimuli (Geršak, 2020). EDA is commonly used for emotion recognition (Horvers et al., 2021), (Posada-Quintero & Chon, 2020) because its high values depict if a user is psychologically aroused, excited, or activated, and its variation from the baseline level (relaxed state) is established as EDA reactivity. The EDA includes two primary components, the tonic and phasic (Veeranki et al., 2021). The first component is the skin-conductance level (SCL), in other terms, the slower changes in electrodermal activity and the latter is the skin-conductance responses (SCR) or the fast pulses that indicate the momentary arousal (Roy et al., 2012). Therefore, the arousal of a user is determined by the total number of SCR pulses per minute. Moreover, SCR pulses are often referred to as peaks, because in the phasic response a burst or a peak is formed in the signal after the interaction with stimuli, thus more peaks indicate higher arousal during an experience (Posada-Quintero & Chon, 2020). Popular devices that are used for GSR monitoring are Emptaica E4 (Cosoli et al., 2021), (Hickey et al., 2021), Biopac BioNomadix MP150 (Ragot et al., 2018), Microsoft Band 2, BodyMedia SenseWear Armband (Saganowski et al., 2020), Affectiva Q EDA sensors (Taylor et al., 2015), and Shimmer3 (Udovičić et al., 2017). Usersence tool utilises Empatica wristbands (*E4 Wristband | Real-Time Physiological Signals | Wearable PPG, EDA, Temperature, Motion Sensors*), which are appropriate for research in laboratory conditions or everyday life (Egger et al., 2019).

Furthermore, a physiological measure that contributes to the recognition of the users' affective states, is the Blood Volume Pulse (BVP) signal, and more specifically the Inter-Beat Intervals (IBI) which corresponds to the time interval between the heartbeats (Udovičić et al., 2017) or the duration of the consecutive heartbeats, also referred as tachogram. A photoplethysmogram (PPG) sensor provides information about the Heart Rate (HR) and the IBI, measuring the changes in the blood volume (a person's level of stress (Choi & Kim, 2018)) (Cosoli et al., 2021). Often, the interbeat interval time determines the variability in the timing of the heartbeat (Hear Rate Variability or HRV) (Thayer, 2017). A PPG sensor is able to detect short-term emotions and it is considered a more suitable option than the electrocardiogram (ECG) (Sayed Ismail et al., 2022) which also provides details about heart-related features. The PPG sensor is embedded in a variety of wearable devices such as Empatica E4 (Bulagang et al., 2020), Huawei Watch 2 (Kim & Baek, 2023), and

Shimmer3 (Udovičić et al., 2017), which are wristband-type wearables in contrast with other PPG-based devices (forehead-type and ear-type) (Castaneda et al., 2018). Usersence aims to use a PPG sensor that is suitable for both lab and everyday activities, and thus, an Empatica wristband will be part of the tool's equipment, as the hand/wrist is indicated for PPG and EDA sensor placement (Schmidt et al., 2019).

Affective state changes correspond to physiological fluctuations that are related to the physiological Autonomic Nervous System (ANS) (Waxenbaum et al., 20219) activity (J. Zhang et al., 2020). Electroencephalography (EEG) can map areas of the brain to emotions because EEG records the electrical field of currents that flow when neurons synaptic excitation appears in the cerebral cortex, depicting the electrical activity of a group of neurons in the sensor's parts (electrodes) placement area (Bota et al., 2019). So EEG acquires the ability to recognize and detect brain waves of individuals while they are performing a task or living an experience (Doma & Pirouz, 2020). The EEG signals are either spontaneous or evoked. The nervous system generates rhythmic potential fluctuations without the influence of external stimuli, naming the spontaneous signal category. When an external stimulus affects an individual then evoked potentials are formed by a detectable potential change in the cerebral cortex. Therefore an EEG signal can be separated into five brain waveforms based on their frequency.

Firstly, Delta wave (frequency: 1-4Hz, amplitude: 20–200 μV) appears in the frontal cortex and it is related to the sleep state, thus during the awake state is imperceptible. Theta wave (frequency: 4–8 Hz, amplitude: 100–150 μV) commonly originates from the temporal lobe and parietal lobe during a calm state. Also, Alpha waves (frequency: 8–13 Hz, amplitude: 20–100 μV) are located in the parietal and occipital lobes and are related to the preparatory activities of the brain, indicating that a person is relaxing with their eyes closed (unnoticeable under the duration of external stimuli). Beta waves (frequency: 13–30 Hz, amplitude: 5–20 μV) appear in the frontal lobe while an individual is resting (eyes closed), but when they start thinking, the waves appear all over the brain regions. The Beta wave replaces gradually the Alpha under strain or stress and it is related to the active or excited state of the cerebral cortex. Finally, Gamma waves (frequency: >30Hz, amplitude: lower than 2 μV) fulfill a significant function in cognitive brain activities and are associated with advanced and complex mental processes, for example, concentration, reception, transmission, and integration (J. Zhang et al., 2020). EEG due to its hardware limitations (set-up requirements, maintenance) is appropriate only for in-lab usage (Egger et al., 2019). There are countless options for EEG headsets as a multitude of companies, such as Emotiv, BIOSEMI, G·tec, Brain Products, and NeuroSky provide a variety of solutions (Soufineyestani et al., 2020). The usersence tool includes Emotiv headsets in its equipment, due to sample rate, set up time, electrode connection type, and the number of channel options the company offers. In the Design section about the hardware of the tool, the selected Emotiv headset will be presented in detail.

Moreover, a wide range of nonverbal communication can transmit emotional states, for example, Facial Expressions (Mortensen, 2017). Facial Expressions offer helpful insights into a UX evaluation in a quick and noninvasive way but should be combined with self-report metrics (e.g. a form with Likert-scale questions) (Albert & Tullis, 2022). To utilise this method for emotion recognition it is essential to include a pipeline framework that is capable of predicting in real-time emotions based on the structure's face or body key points. MediaPipe (*MediaPipe*) framework has been used for such procedures ((Siam et al., 2022), (F. Zhang et al., 2020), (Subramanian et al., 2022), (Savin et al., 2021)) as it can detect objects and face landmarks (Lugaresi, Tang, Nash, McClanahan, Uboweja, Hays, Zhang, Chang, Guang Yong, et al., 2019). A developer can use MediaPipe to create prototypes and polished applications because it is an open-source framework (Lugaresi, Tang, Nash, McClanahan, Uboweja, Hays, Zhang, Chang, Yong, et al., 2019). A web camera on the participant's computer screen captures their facial expressions, and as a result, the user must be in a sitting position in front of the camera with proper room lighting. For this reason, Usersence offers a Facial Expression analysis only for the evaluations conducted inside the laboratory.

Additionally, Questionnaires belong to the self-reported data because the participant has to describe how they feel about the system interaction. Usually, a rating scale is used to capture the degree of agreement with a statement (Albert & Tullis, 2022). For instance, a Likert Scale contains a series of statements (positive or negative) and a 5-point scale of agreement (1. Strongly disagree, 2. Disagree, 3. Neither agree nor disagree, 4. Agree, 5. Strongly agree) providing to the user the opportunity to express their opinion (Taherdoost, 2019). Also, self-assessment can be achieved for emotion measurement through specific questionnaires such as Self-Assessment Manikins (SAM) (Bradley & Lang, 1994), and the e Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988). Firstly, the SAM questionnaire is a series of drawings that visually depict valence, arousal, and dominance. Each section consists of five drawings that correspond to specific points. Valence (section A) estimates the level of pleasant or unpleasant feelings, arousal (section B) indicates the range between excitement and calmness, and dominance (section C) defines emotional states from controlled to uncontrolled. The PANAS questionnaire consists of twenty different words (ten positives, ten negatives) that describe a possible affective state that emerged before, during, or after system interaction. The participant must rate each word between one (Very slightly or not at all) and five (extremely), to form the total score for each column. The positive affect (PA) and the negative affect (PA) scales have a score range from 10 to 50. The higher the score, the greater the affect (Bota et al., 2019). Usersence includes customizable Likert Scale questionnaires because they are easy to read and complete by the participants during the UX evaluation with or without being monitored through biosensors.

Furthermore, Usersence integrates two more data that are considered essential by the design and development team of the tool, for the UX evaluation.

Participant’s location and video footage of the user’s perspective are considered important aspects of the experience and thus will be recorded using a mobile phone and an action camera on a head strap. GPS data offers information about the user’s movement in a large-scale environment (outdoor space/ evaluation in the field) and the video footage contributes to stimulus origin tracing. More specifically, GPS and video footage, in combination with physiological monitoring, could assist in evaluating the urban environment that evidently affects the well-being of individuals ((Guite et al., 2006), (Douglas, 2012)).

Usersence Tool Design

Usersence is a collection of software, and self-report methods that assemble information to identify users' affective states, enabling evaluators to gather data for analysis and decision-making, utilizing commercial devices. The tool supports wearable and mobile devices that allow psychophysiological data recording, facilitates the physiological signals and self-report responses processing, guides the evaluators at every step of the procedure offering them the opportunity to utilize such practices even though they are not specialized in them, provides information about users' emotional states in relation with time, location and environmental conditions of the evaluation, visualizes recordings' results on a main UI (User Interface) screen per user, and finally processes imported data locally, avoiding any server infrastructure and maintenance for data uploadings. Also, Usersence is directed towards usability experts, UX researchers, designers, product developers, and workshop facilitators who seek to utilize practices that enrich traditional evaluation methods and are eager to collect valuable and meaningful insights into the multifaceted aspects of the UX.

As has already been mentioned, the Usersence tool utilizes biosensors, and mobile and video capture devices to monitor the participants' affective states during a UX formative or summative evaluation. The selected physiological signals, that the tool processes, are IBI, EDA, EEG, and facial expressions, and additionally, self-report metrics are included (Likert Scale Questionnaires) as well as the user's location and video footage. Usersence combines different data based on its context of use. More specifically, the tool's structure, in other terms the combination of biosensors, mobile, and video capture devices, varies depending on the location of the evaluation. In the field (outdoor space, long-scale environment), EDA, IBI, and GPS data, video footage, and questionnaires are the primary recordings, as opposed to the laboratory (indoor space, seated or restricted area, room-scale environment) where the IBI, EDA, EEG and facial expression data and questionnaires are the main source for emotion recognition.

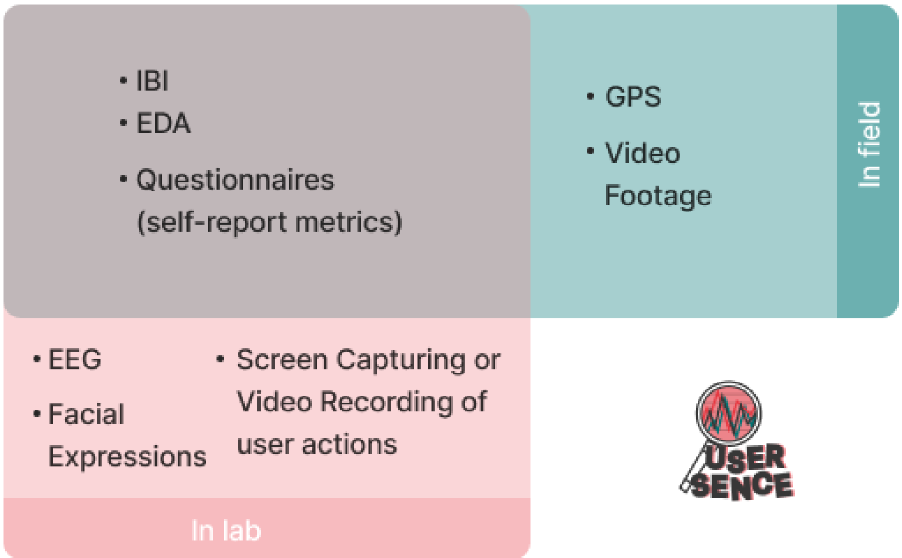


Image 1: Tool structure

Therefore, an evaluator should first decide the location of the procedure to prepare the needed devices appropriately. In the lab, the involved devices are the EEG Emotiv headset, the web camera for facial expression recording, the Empatica wristband (IBI and EDA data gathering), and the action camera for user reaction recording or the screen recording function, which is considered a promising option. In the field, the Empatica wristband, the mobile phone (GPS, self-report questionnaire), and the action camera will be used to record the essential data for the UX evaluation.

As soon as the participant has worn the selected devices, they must remain in a neutral state, in a seated or standing position, for at least five (5) minutes for the baseline to be measured. The recommended evaluation duration is fifteen (15) minutes to thirty-five (35) minutes, including the baseline measurement time. When the evaluation begins then the participant is free to complete the requested tasks, as the evaluator described. Also, when considered necessary during the experience, the participant must complete a questionnaire displayed on the Usersence's mobile application. This procedure may be repeated until the fulfillment of the evaluation's tasks by the participant. The evaluator after the recordings is responsible for collecting the data from each wearable or mobile device and inserting them into the tool's folder system.

Thus, the Usersence analysis platform will be able to display a diagram or in other terms, the experience chart for each participant of the evaluations. The aforementioned steps are visualized in the following storyboard. Additionally, according to Albert and Tullis (2022), the appropriate number of participants varies from five (5) to ten (10), especially when the evaluation aims to identify the most important and critical issues of the experience and the participants belong to the same user group, such as citizens in the neighborhoods of the HertitACT's pilots.

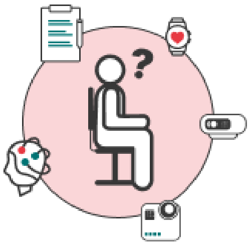
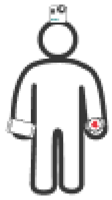
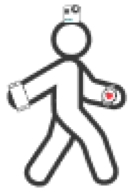
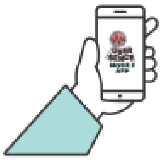
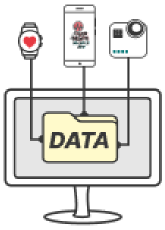
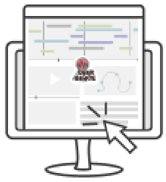
	 Evaluation in the field set-up	 During the evaluation
1. Decide the evaluation category (location and devices).	2. Record the user's baseline.	3. Let the user perform the tasks.
 Tool's mobile app		 Tool's visualization app
4. Request self-report input.	5. Insert devices' data into the Analysis Command Line Application.	6. Generate user's experience chart.

Image 2: Usersence Storyboard

Moreover, the steps of the tool's procedure are presented below in sequential order, as they determine the evaluation outcomes. The Usersence flowchart depicts the phases for which detailed instructions will be provided in the user manual to assist evaluators in integrating Usersence into UX evaluations. These phases involve selecting the location type for the evaluation and preparing the devices and the participants (how they wear and use the equipment), recording the baseline, as it is important for the physiological data processing and analysis, combining signal recording and self-report metrics utilization, saving the data from each device to the tool's folder system, and creating and understanding the experience chart (evaluation diagram per user). The experience chart is the primary objective of the Usersence tool because it provides evidence to support decision-making processes related to potential adjustments or feedback on the overall design of an experience.

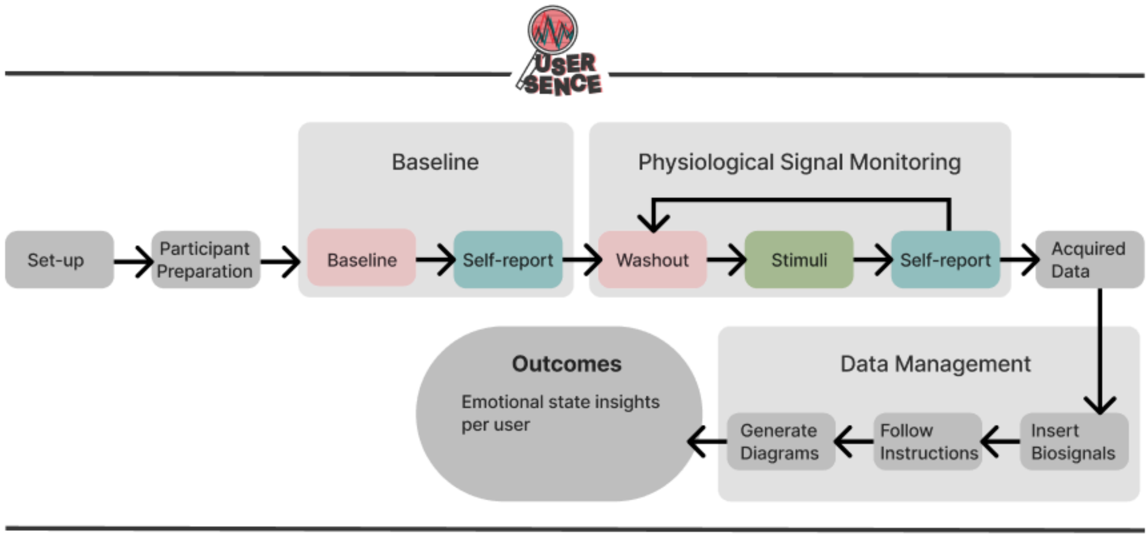


Image 3: Usersence Flowchart

Additionally, the suggested tool's equipment consists of wearable and mobile devices that are recommended for use to collect the necessary data to enable the Usersence analysis platform to produce the experience chart. The equipment includes A) 1 x Empatica E4 wristband, B) 1 x GoPro Max action camera, C) 1 x Samsung S21 Ultra mobile phone D) 1 x Logitech C615 WEBCAM, and E) 1 x Emotiv Flex Gel Sensor Kit 2.0 EEG headset. In the figure below, the connection between the tool's devices and data is presented. The Empatica wristband offers IBI and EDA data, the GoPro camera generates a user's point-of-view video, the Samsung mobile phone delivers the location data and stores the questionnaire answers, the Logitech webcam assists in the facial expression video recording, and the Emotiv headset captures EEG data. The commercial devices are recommended because they are considered appropriate to obtain the data that the tool requires based on the location of the evaluation.

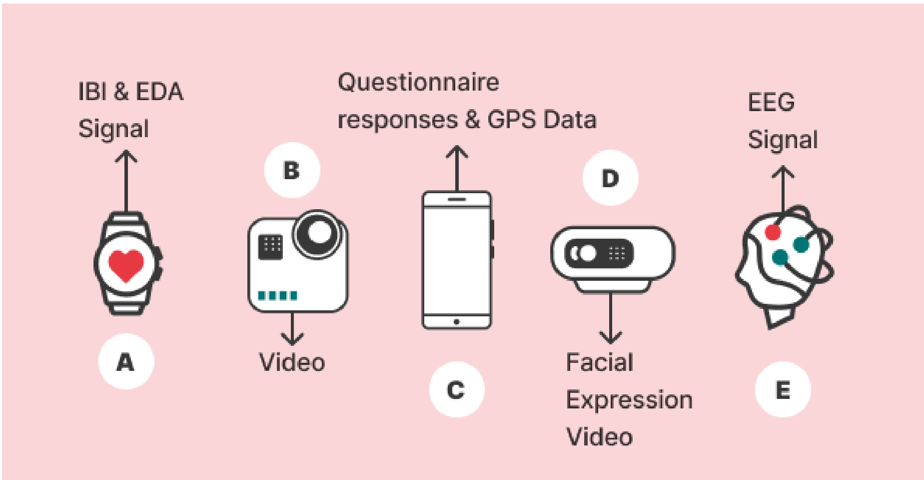


Image 4: Usersence Hardware

Firstly, the Empatica E4 wristband is equipped with a photoplethysmography (PPG) and an electrodermal activity (EDA) sensor, a 3-axis accelerometer, and an optical thermometer, producing BVP (@64Hz), IBI, EDA (@4 Hz), XYZ raw acceleration (@32Hz), and skin temperature (@4Hz) data, accessible in CSV format through the E4 Connect dashboard (Garbarino et al., 2014).

Image 5: Empatica E4 wristband

Also, the GoPro MAX action camera transfers files via a USB-C cable, has a video resolution of 5.6K 30fps, maximum stability, and horizon leveling, and a battery capacity of 1600 mAh. The tool includes this camera to capture the user's perspective, producing an mp4 file requiring a microSD card, and its head strap (*GoPro MAX 360 Action Camera*).

Image 6: GoPro MAX action camera

The Samsung Galaxy S21 Ultra 5G serves as the main mobile device equipment for tracking the user location routes and storing the questionnaire responses of the Usersence mobile application. The phone is able to transfer files to the tool's folder system using a USB Type-C, is equipped with the appropriate location technology (GPS, Glonass, Beidou, Galileo), and has a battery capacity of 5000 mAh, and an Android operating system ensuring an optimal performance and data collection reliability (*Galaxy S21 Ultra, S21 Plus & S21 5G | Samsung Greece*).

Image 7: Samsung Galaxy S21 Ultra.

The web camera for facial expression video recording is the Logitech C615 WEBCAM which has an HD autofocus and a resolution of 1080p/30 fps - 720p/ 60 fps. The camera is attached to a USB-A cable, fixed to a mounting clip, and is compatible with Windows 8 or later versions (*Logitech C615 Full HD Webcam*).

Image 8: Logitech C615 WEBCAM.

Finally, the required EEG headset is the Flex Gel Sensor Kit 2.0 which consists of the silver silver-chloride sensor tips (34 sintered silver-silver chloride gel sensors, and compatible ear clips), a compact control box fitted to the cap, flex cap, and USB charging cable. Data acquisition requires an account to the Emotiv application and a License for use.

Image 9: Flex Gel Sensor Kit 2.0 (*EPOC Flex*).

Usersence consists of both wearable and mobile devices, and software, which are essential for data processing and experience chart creation. The tool is accessible through the HeritACT Toolkit's website, which directs the users to the repository. There the instruction folder is available for download, containing the Visualization Platform, the Mobile App, and the user manual. The manual presents all the necessary information for the effective use and integration of the tool in the evaluation procedure, for instance, information about the installation, storage, and cleaning of the devices, data acquisition and management, and experience chart configuration. The Mobile Application, the Analysis Command Line, and Visualization Platform are the main software components. The Mobile Application tracks the user's path location while displaying the customizable questionnaire based on a Likert Scale. The Analysis Command Line Application receives all the logged data which leads to the description of the user's emotional state (experience chart per user) through the Visualization Application. Furthermore, data visualization is achieved through the app which includes a specific procedure to effectively provide its results, in other terms the experience chart. This chart depicts a common timeline of all the imported data into its folder system.

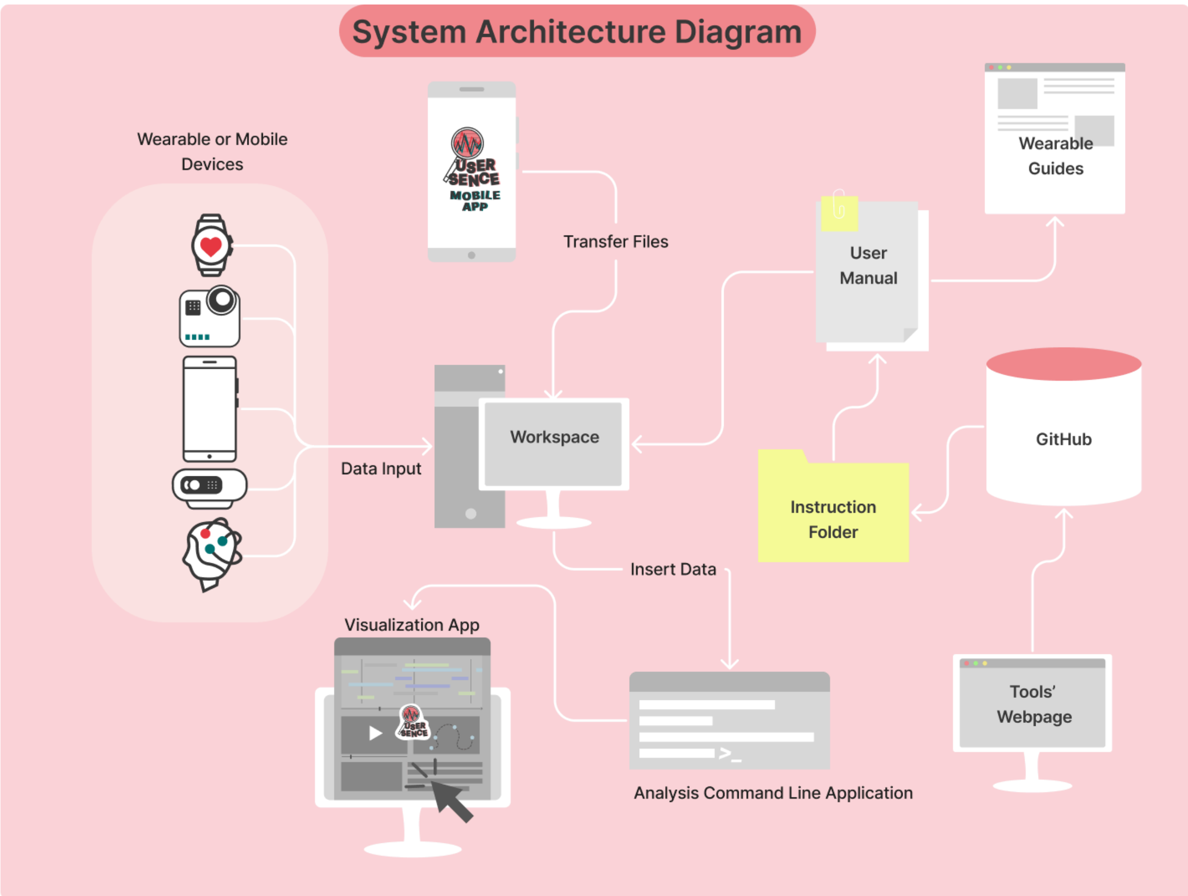


Image 10: Tool (System) Architecture

From Web to Desktop

In this section, the procedures to follow upon downloading the Usersence zip file from either the tool's website or its repository. Firstly, you should decompress the file:

1. Right-click on the file.
2. Select "Extract All".
3. Follow the instructions on the pop-up window:
   a. Select a folder destination where the file will be extracted.
   b. Optionally, click "Browse" to select a different folder than the one already displayed.
   c. Click "Extract".
4. Go to the destination folder you selected and double-click the installed Usersence folder.

Inside the Usersence folder, you can find:

- The Usersence User Manual.
- The Usersence Mobile Application (SenceMob.apk).
- The Analysis Folder with the analysis.exe file.
- The Visualization Application (SensViz.exe).
- The Experiment Folder Template which includes:
  - The configuration file (config.txt).
  - The sample of the Folder Structure.

Device Setup and Installation

Usersence device setup varies based on the selected location of the evaluation. In this chapter, the involved devices are presented per case, more specifically if the evaluation is conducted in the field or the lab. Firstly, the wristband, the smartphone, and the action camera are presented as they are the main equipment setup for the field evaluation and afterward, the webcam, the EEG headset, and the video recording method (screen capturing or video recording through the action camera) are presented as the primary devices of the in-laboratory evaluation. It is essential to emphasize that the wristband and the smartphone, are also recommended as part of the in-laboratory equipment setup but because they will be presented thoroughly previously, only some modifications will be noted due to the change of context (location).

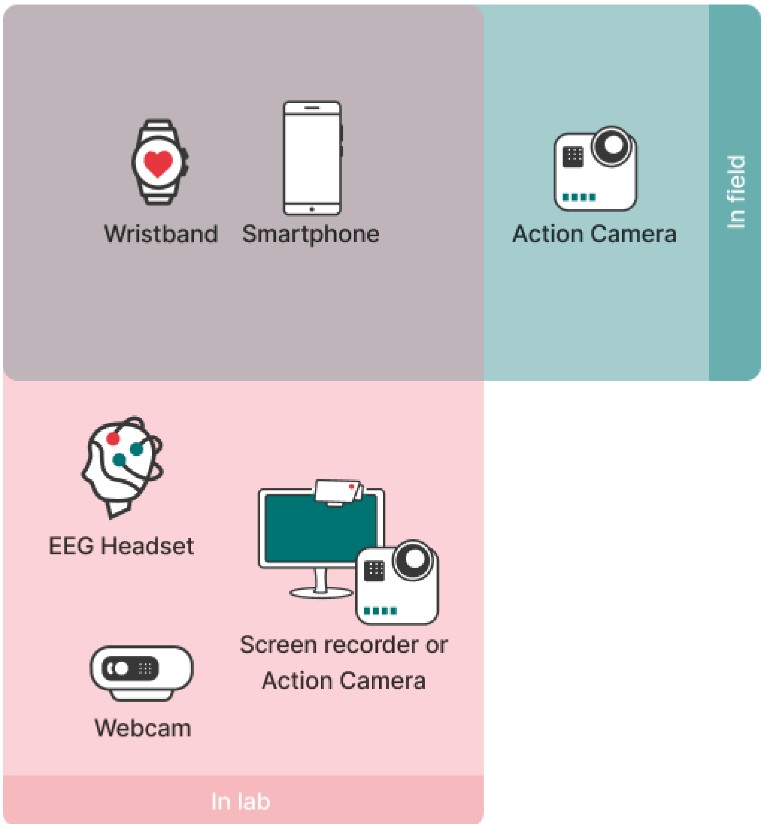


Image 11: Devices based on location.

In-field Device Setup

Empatica Wristband

The Empatica E4 wristband is a wearable device that monitors physiological data in real-time, and it is part of the Empatica Research platform that includes the E4 realtime (for Bluetooth Smart Android devices), E4 manager (Windows), and the E4 connect web application. The E4 wristband records the physiological signals and depending on the operating mode (streaming or recording mode), the E4 connect platform allows you to organize and download the recorded data. Usersence suggests using the E4 wristband in recording mode, utilizing the E4 manager for sessions' uploading into the E4 Connect web platform, because of the E4 realtime mobile application's limited compatibility with some smartphones. Through the USB dock and the USB MICRO-B cable, the E4 wristband can connect to your computer (PC) and transmit its data to the E4 manager.

Before use:

- Ensure that the E4 wristband is charged properly according to the device's manual (E4 wristband user's manual or search the file in Empatica user manuals) with the USB dock and the USB MICRO-B cable.
    - The wristband's LED indicator light should turn yellow when it is charging but is turned off.
- Download and install the E4 manager into your computer.
    - When you insert the wristband's USB into your computer, but the E4 manager can not detect the wristband, then you should install the E4 USB Drivers by yourself, following the instructions as mentioned in the lower paragraph on the support center page about: "E4 manager installation issue on Windows"
- Create an Empatica Connect account because it is necessary to log in to E4 manager and E4 connect.
- Decide how you will use the wristband's tags.
    - The wristband's button, when tapped, creates a tag in the recorded data.
    - Usersence uses tags either to allow the participant to enter the timestamps (beginning and end) of the evaluation stages or to mark events that the participant considers important during the evaluation. The evaluator must choose beforehand the tag interpretation, to explain to the participant how and why (for what reason) to use the button to create tags.

During use:

- Usersence suggests wearing the E4 wristband on the top of the participant's wrist on the dominant hand.

- Press the wristband's button for 2 seconds to turn it on. A steady red light indicates that the recording has started (the LED indicator after a few seconds will switch off, but keep in mind that the recording will continue until you press the button for 2 seconds and turn off the device).
- Tap the button once (less than 1 second) to create a tag (a red light will flash for about 2 seconds during recording, indicating that the tag has been registered).
- Press the wristband's button for 2 seconds to turn it off.
- Remember, when the LED indicator light alternates from red to yellow repeatedly, then the wristband is out of battery and needs charging.

After use:

- Connect the wristband to your computer with the USB dock and the USB MICRO-B cable.
- Log in to the E4 manager, using the email and password of your E4 connect account, and upload the recorded sessions to the E4 connect platform.
- Log in to your E4 connect account, and download your data via the web dashboard.
- Remember it is important to maintain and care for the wristband, ensuring its clearness after each participant's evaluation process, by cleaning it with cotton soaked in a small amount of ethyl or isopropyl alcohol.

Notes:

Please consult the E4 wristband user's manual for more information about device wearing advice (4. Wearing the E4 wristband) and the LED light indications (5. Interacting with the E4).

Smartphone

The mobile phone serves as the device that collects self-report and location data, hosting the Usersence mobile application. The Usersence mobile application can be installed when the Developer options of the Android device (Samsung Galaxy S21 Ultra 5G) have been enabled. This option allows you to configure your system smartphone behaviors regarding its applications, but the Developers options menu is hidden by default. To activate the Developer options:

1. Go to "Settings".
2. Scroll down and tap on the "About phone" or "About device" menu.
3. Tap on "Software information" (only for Samsung smartphones)
4. Tap seven (7) times on "Build number" until the indication: "You are now a developer" is displayed.
5. If you have a password, PIN, or pattern, you must enter it to confirm the activation of the Developer options menu.
6. The "Developer options" menu is now enabled and displayed in your Settings.

Furthermore, using a USB-C to USB-C cable, connect the smartphone to your computer or download the Sensmob.apk from a cloud folder (e.g. Drive), to install the

Usersence mobile application, create a destination folder and move there the SensMob.apk file to your smartphone's folder. Then:

- Disconnect your device.
- Launch the Usersence Mobile App on your smartphone.
- Allow GPS access while ising the app.

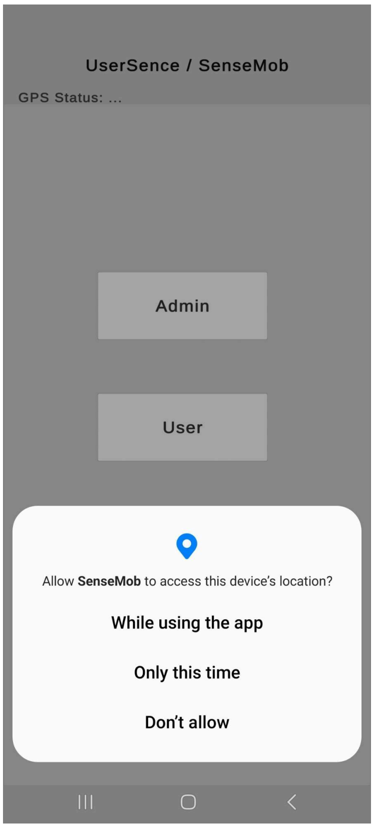


Image 12: Allow GPS access.

- Exit the the app and connect again the smartphone to your computer, your mobile phone should be detected as a device.

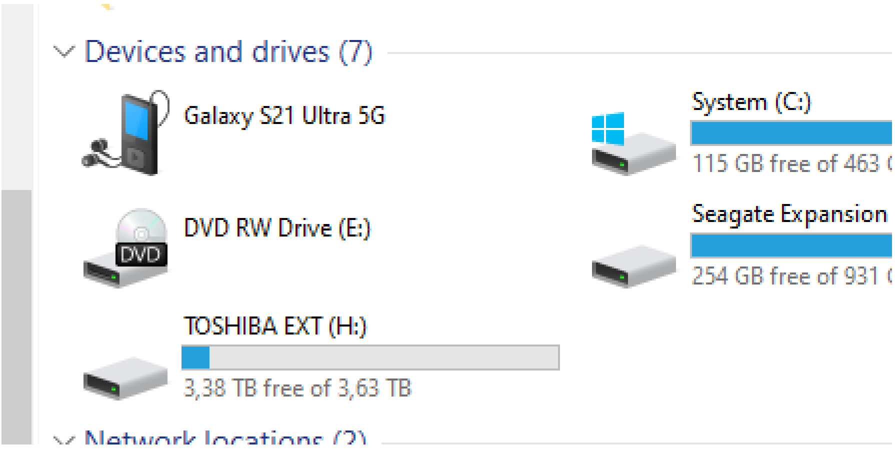


Image 13: Smartphone detected as a device.

- Open the folder following the directory: **Android\data\com.ISDLabAegean.SenseMob\files** and open the file config.txt which contains certain customizable options:

Configuration Settings	Notes
#configuration file for the evaluation questionnaires #activation can be location, button or time #location is activated once for each of the saved locations #that the user approaches within the defined range #time is activated repeatedly in a given frequency #button is activated on demand when the user presses a button	The questionnaire includes one customizable question that reappears depending on the activation value: 1. button 2. time 3. location
activation=button	How the questionnaire is activated.

#button name is for button activation
buttonName = Evaluate!
	The word that's on the button which causes the questionnaire to appear when the participant presses the button.
	Only available when: activation=button

#frequency is for time activation, in minutes
frequency=2
	How many minutes will take for the mobile app to open the next question.
	Only available when: activation=time

#range is for location activation in meters
range=10
	The distance (m) from the pre-saved locations. This value forces the questionnaire to

	appear when the participant is within range of the location. Limitation: only one question per location. ***Only available when: activation=location***
title=How are you feeling right now? question1=very sad question2=sad question3 = neutral question4=happy question5 = very happy	The question and the answer options of the self-report questionnaire.

Table 1: mobile configuration file options.

- Choose the activation option and save the mobile configuration file.

Before use and once the installation is completed:

1. Open the Usersence mobile app and tap on “Admin”.

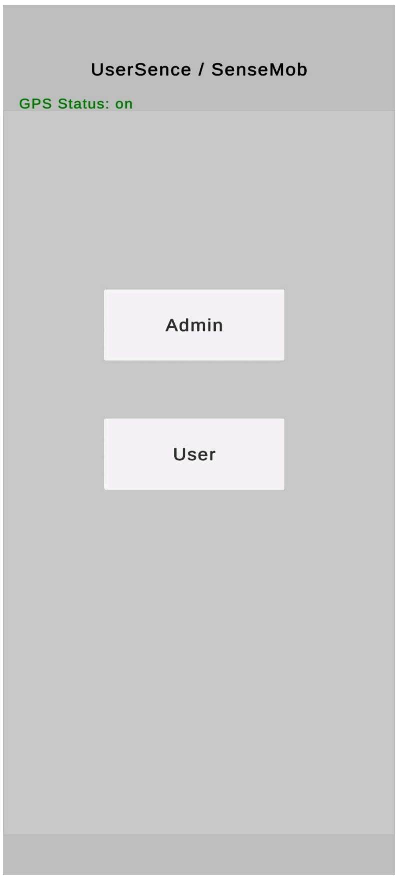


Image 14: First Usersence Mobile Screen.

2. On that menu, you can:
    a. Check if the Location (GPS) of the smartphone is activated.
        i. The GPS Status must be on (indication on the top left corner of the mobile screen).
    b. Verify the activation mode of your choice (location, button, or time-based) and the name of the button in case of button activation mode.

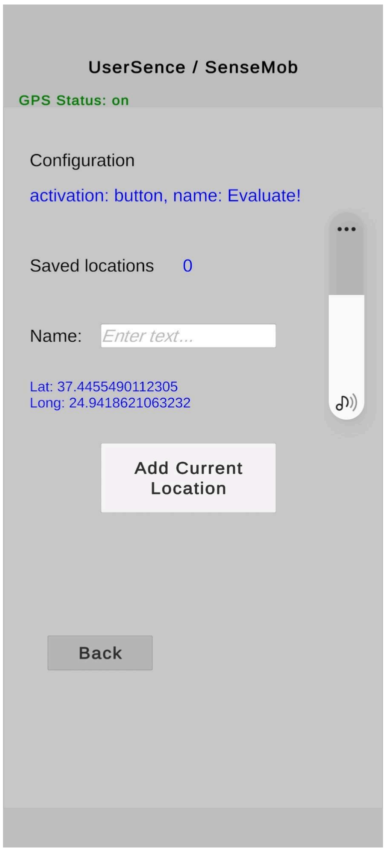


Image 15: Admin Screen & **activation = button**.

    c. Verify how many times the questionnaire will be displayed (saved locations).
    d. Add a location by:
        i. Walking to the place of your choice with the smartphone in hand.
        ii. Enter a name for your place in the “Name” section, for example “home”.

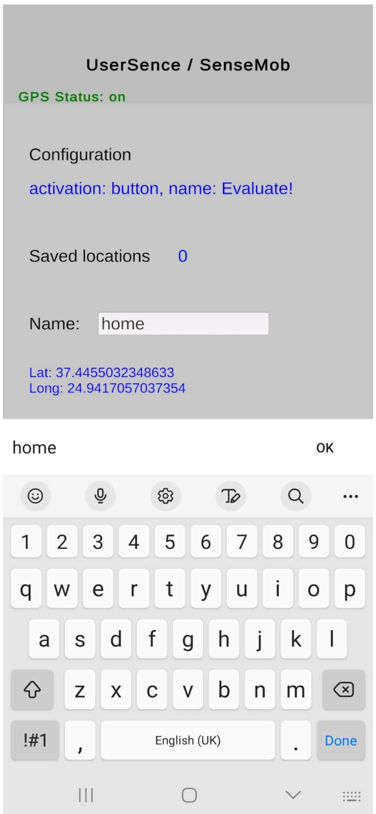


Image 16: Save a Location.

iii. Press the “Add Current Location” button and verify the change of the “Saved Locations” number.

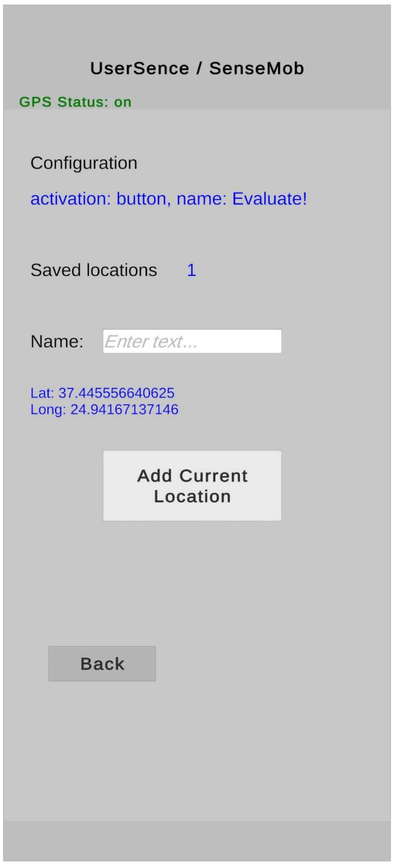


Image 17: Successful Location Addition.

During use:

- Open the Usersence Mobile app and tap the “User” button from the first Usersence Mobile Screen (image 14).
- Give the smartphone to the participant.
- Offer the the follow instructions:
    - Press the “Start” button a few moments before the activity of the evaluation begins.

Image 18: Start recording & button activated question.

- Press the “Evaluate!” button when you want to record a self-report response.
  - In case the activation value varies:
    - If activation = frequency, then after some minutes the question will pop-up automatically.
    - If activation = location, then the participant will trigger the question in case they are near the pre-saved location that has been added beforehand.
- Do not press the “Stop” button, because the process will be interrupted.
- Tap the response you want to choose and tap the “Confirm!” button which appears only if an answer is selected.

Image 19: Answer options and confirmation.

- Stop the Usersence Mobile App by pressing the "Stop" button two times in a row.

After use:

- Connect your smartphone to your computer with a USB-C to USB-C cable.
- Select the Transferring files or File transfer option on your smartphone.
- Open the folder following the directory: **Android\data\com.ISDLabAegean.SenseMob\files**
- Near the config.txt file two new file types will be created for each participant in the evaluation: A)path1.csv and B)responses1.csv. If you have more than one participants then you will have more path/responses pairs.
- Connect your smartphone to your computer, and copy the files (path1.csv and responses1.csv) to it.
  - You can delete the path and responses files from the smartphone in case you want to star the numbering sequence from the beginning for the next time. Otherwise the number extension in the files will be getting bigger.

Notes:

- Remember to charge the smartphone before use.

- Keep the device's Location (GPS) on during the evaluation.
- Adding Locations is mandatory when: **activation = location**.
- Explain to the participants how to use the app before the evaluation begins.

Action Camera

The action camera that is recommended to use is the GoPro MAX camera with its head strap, to record the participant's perspective during the evaluation in an outdoor space. In this way, the evaluator can have a point-of-view (POV) video, when they examine the insights on the Usersence Visualization App after the evaluation. More specifically, the evaluator can associate the participant's state with the video time and thus to the participant's activity during the evaluation. The GoPro MAX action camera includes:

- Two rubber-protecting lenses to protect the camera lenses when the camera is being stored.
- A curved adhesive mount.
- A MAX battery.
- A Mounting base with thumb-screw.

Before use:

- Insert the MAX battery.
- Insert the microSD card.
- Charge the action camera using the USB-C cable.
- If necessary update the firmware manually (Manual Update) or using the GoPro app.

During use:

- Record a video by pressing the record button on the top of the camera.
- Keep the settings on default (1080| 60|W).
- Record in Hero Mode which is the regular or traditional video (not a 360° Video).

After use:

- Transfer video files by selecting one of the following options:
  - The USB-C cable that connects the action camera to your computer.
  - microSD adapter.
  - The GoPro application on your mobile phone.

Note:

- It is suggested to transfer video files using the USB-C cable.

In-lab Device Setup

During a laboratory, evaluation more devices can be utilized, and the participant should be in a seated position to ensure accurate measurements. These devices also include the Empatica wristband and the Usersence mobile application, only for questionnaire response gathering, as presented in the previous section of the Usersence User Manual.

EEG Headset

The Emotiv Flex Gel Sensor Kit according to the EPOC FLEX User Manual includes a wireless control box (FLEX controller), thirty-four (34) multi-rode gel sensors manufactured from sintered Silver/Silver Chloride that are compatible with gel electrolytes, two ear clips, a head-cap, a universal USB receiver and a Micro-B to A USB charge cable. The EEG data are accessible via the EmotivPRO desktop application, which requires the EMOTIV Launcher which ensures the connection between the hardware (Emotiv Flex Gel Sensor Kit) and the software (EmotivPRO Lite).

Before use:

1. Charge the FLEX controller with the Micro-B to A USB cable.
2. Insert the Sensors into the cap.
    a. Sensor wires are color-coded, blue for left, red for right.
    b. Map the sensors in the EPOC X configuration to gather the performance metrics.
3. Place the FLEX controller in the rear head position.
4. Tidy up the wiring to secure the sensors' placement.
5. Plug the white connectors (attached at the end of the red and blue wires) into the FLEX controller.
6. Create an Emotiv ID (Emotiv account).
7. Install the EMOTIV Launcher and the EmotivPRO Lite.

During use:

1. Log in to your Emotiv ID account both in EMOTIV Launcer and EmotivPRO.
2. Turn on the FLEX controller (the LED indicator light will turn orange if the controller is fully charged).
3. Connect the USB receiver to your computer.
4. The EEG headset will appear on the available devices and click "Connect".
5. Click the "Connect Headset" button on the EmotivPRO application.
6. Follow the instructions about the device fitting, contact quality, and EEG quality.
    a. Using a cotton swab carefully move the hair below the sensor opening, tip the cotton swab into isopropyl alcohol, and degrease the skin by rotating the cotton swab inside the sensor opening.
    b. Using a small syringe, fill the sensor opening with electrolyte gel (e.g. Nuprep).
7. Achieve the highest EEG quality (green indication) to ensure that your EEG data are accurate.
8. Record your session, by pressing the record button to begin and the stop button to complete the recording session.

9. Export the EEG data recording.
10. Disconnect the headset before unplugging any device and turn off the FLEX controller.

After use:
1. Remove the FLEX controller from the cap.
2. Secure the white connectors, which are attached at the end of the red and blue wires, with a zip lock bag and seal them using a rubber band to protect them from getting wet (they must remain dry, hold them out of water).
3. Clean the gel sensors immediately after each use, before the electrolyte gel starts to dry.
    a. Follow the cleaning instructions carefully to avoid damaging the EEG headset.

Webcam

Usersence tool, requires a video recording of the participant's face, to detect emotional states based on their facial expressions. The webcam must be placed at the top of your computer screen or in the main area of interest of the participant during the evaluation, capturing the participant's face. Also, the webcam must be connected to your computer via its USB cable to record an mp4 video through the Windows Camera application (standard camera app on Windows).

Note:
- Pay attention to the light, it must be consistent and clear throughout the recording.
- The camera must be placed in a suitable position to record the participant's face accurately.
- Use the Windows Camera application to record the video.
- Begin recording after completing the EEG headset and Empatica wristband setup, a few moments before starting the evaluation procedure.

Screen recorder or Action Camera

The Usersence tool supports the input of additional video in an In-Lab evaluation, which captures the user during the procedure. Screen recording is recommended when the evaluation involves computer (screen-based) interactions or recording the participant's activities utilizing the action camera, which in his case can be placed on a vertical surface or a tripod rather than on the participant's head. A few moments before the evaluation begins, activate the screen recording option of Windows by pressing the Windows logo key + G on the keyboard to open the Game Bar menu. If the evaluator prefers to use the action camera, they should follow the instructions in the previous chapter regarding the Action Camera, except that they should place the camera in such a position that the participant's actions and movements are recorded accurately.

File Organization & Data Analysis

The file collection from individual devices and applications should be performed carefully so that the data can be analyzed and eventually visualized. Every device and its software exports specific file types that must organized accordingly. The evaluator should gather the following files from the exported data from each device software (Empatica Connect, Usersence Mobile App, EmotivPRO) or the files produced from each device (recorded videos) or the files from the main Usersence Folder, which the evaluator unzipped. The required files are:

- From the Usersence Folder:
    - config.txt
- map.txt
- From the E4 connect:
    - EDA.csv
    - IBI.csv
    - tags.csv
- From the Usersence Mobile App-smartphone:
    - path.csv
    - responses.csv
- From the webcam and the standard Windows Camera application:
    - faceVideo.mp4
- From the action camera or the screen recorder:
    - videoRecording.mp4
- From the EmotivPRO:
    - eeg.csv

Moreover, it is critical to clarify that the configuration file (config.txt) provides the ability to make customizable options and thus is fundamental to elucidate its layout. The tool development team has set certain values and benchmarks as a default, and potential changes are optional depending on the evaluator’s judgment. After each change, the configuration file must be saved and transferred into the Main Folder, which the evaluator must create (more information about the file organization in the Folder Structure System section). The configuration file includes information for both the analysis and the visualization procedure.

Below the variables that are used by the Analysis App or the Command Line Application are presented based on the EDA Explorer (Taylor et al., 2015) and the heart rate variability metrics (Shaffer & Ginsberg, 2017):

- ***eda_thres=0.7:*** (measured in microSiemens or μS), the minimum amplitude that a skin-conductance response (SCR) must reach to be counted as an SCR.
- ***eda_offset=1.0:*** (measured in seconds), the number of seconds for which the derivative must be positive before a peak and the number of seconds for which the derivative must be negative after a peak.
- ***eda_start_wt=4:*** (measured in seconds), the maximum number of seconds before the apex of a peak that is the "start" of the peak.
- ***eda_end_wt=4:*** (measured in seconds), the maximum number of seconds after the apex of a peak that is the "rec.t/2" of the peak, 50% of amplitude.
- ***ibi_window_size=120:*** (measured in seconds), stress calculation time based on the interbeat intervals (IBI), and more specifically the root mean square of successive IBI differences (RMSSD feature).
- ***facecam_freq=2:*** how many frames per second are processed to identify the participant’s facial expressions (the higher its value, the more analysis time is required).

The Visualization App utilizes the following variables:

- ***experiment = My evaluation:*** session name
- ***eda_high_perc = 0.1:*** percentage in comparison with the threshold by which the EDA peak is considered High, otherwise it gets the medium value.
- ***eda_very_high_perc = 0.2:*** percentage in comparison with the threshold by which the EDA peak is considered Very High.
- ***eda_values = medium,#cddce4, high,#bad1dd, very high,#a5c7d8:*** labels and colors, in HTML HEX format, for the three EDA peak values.
- ***eda_graph_color = #a5c7d8:*** EDA graph color
- ***ibi_high_perc = 0.2:*** percentage in comparison with the baseline, in which the stress value is considered High.
- **ibi_very*_high_perc = 0.3:*** percentage in comparison with the baseline, in which the stress value is considered Very High.
- ***Ibi_values = baseline,#e5e5e5, very low, #dfe7eb, low, #dfebe5, medium, #ebe9df, high, #ebe4df, very high, #ebdfe2:*** labels and colors of the six Stress values, including the baseline.
- ***ibi_graph_color = #ebdfe2:*** IBI graph color.
- ***tag_type = state:*** E4 tags’ type (state or event). States have a duration and thus they divide the timeline, while events are instantaneous or momentary.
- ***Tag_values = onboarding, #eeeeee, first task, #eeffee, second task, #eeeeff, reflection, #eeeeee:*** tags’ values, the name of the states or events and their colors. If there are N tags then N events or N+1 states are formed. If any value is missing the last one is repeated.
- ***Facecam_values = angry, #ebdfdf, disgust, #e5ebdf, fear, #e5dfeb, happy, #ebebdf, sad, #dfdfeb, surprise, #ebe5df, neutral, #e5e5e5:*** labels and colors of Facial Expressions.

- ***map_top_left = 37.44585,24.94123***: top left corner of the map in latitude, longitude, this value changes depending on the location of each evaluation.
- ***map_bottom_right = 37.44485,24.94288***: bottom right corner of the map in latitude, longitude, this value changes depending on the location of each evaluation.
- ***gps_graph_color = #d0d0d0***: color graph of the walking path.
- ***response_type = satisfaction***: questionnaire topic
- ***response_values = not at all, #eff4ef, little, #dfebdf, medium, #cde4cd, high, #baddba, full, #a5d8a5***: labels of the five values of the mobile questionnaire answers and their colors.

In addition, the Main Folder contains an image of a map (map.png) which serves as the background of the walking path display screen, when the evaluation is conducted in the field and GPS data are recorded via the Usersence Mobile App. The evaluator must create the map image and then insert it into the Main Folder and update settings, by making changes to the configuration file and updating the values of the variables: ***map_top_left*** and ***map_bottom_right***. In order to make these changes, the evaluator should use OpenStreetMap to generate the map image background and calculate the values of the variables. In order to demonstrate the use of the website, an area of Hermoupolis will be used as an example. The evaluator will have to locate their desired area on the map, following the instructions below:

1. Go to the OpenStreetMap website and locate the area you want.

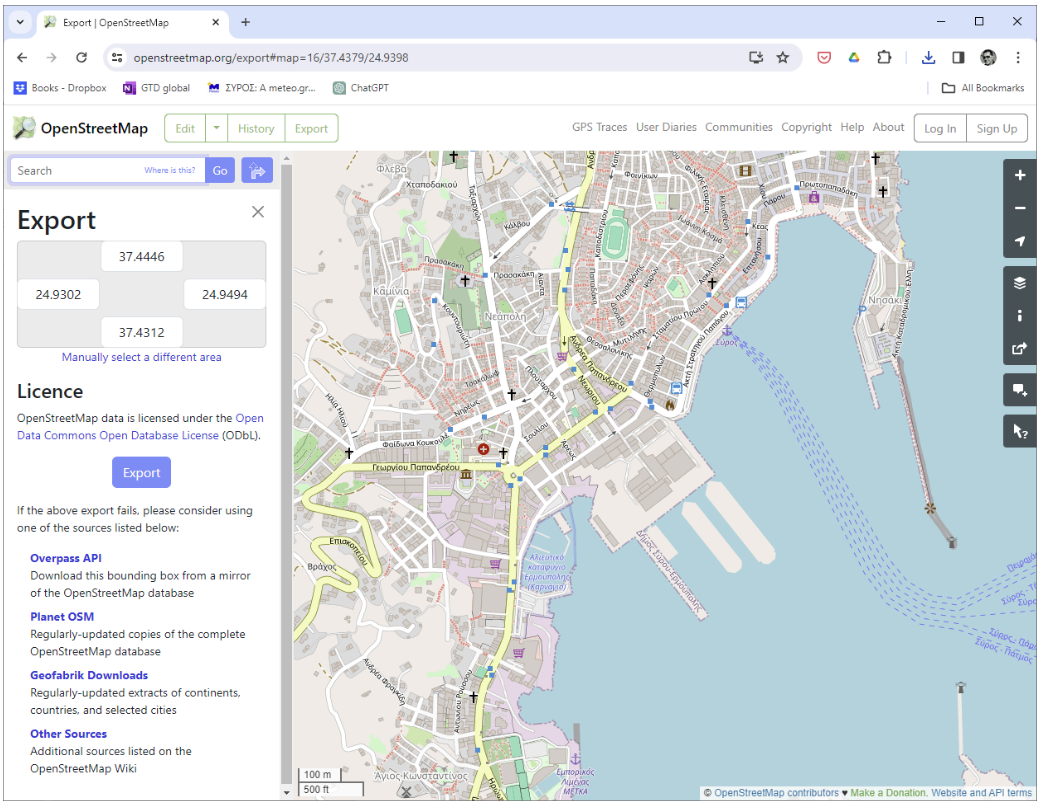


Image 20: Selected Area of Hermoupolis.

2. Click on the “Share” Icon.

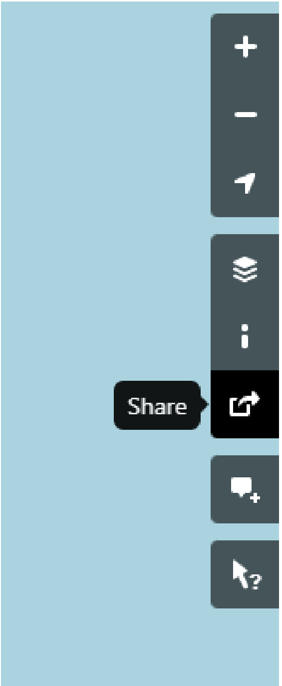


Image 21: “Share” Icon.

3. Click on the white box “Set custom dimensions”, on the lower side of the Share Menu and adjust the area setting box as desired.

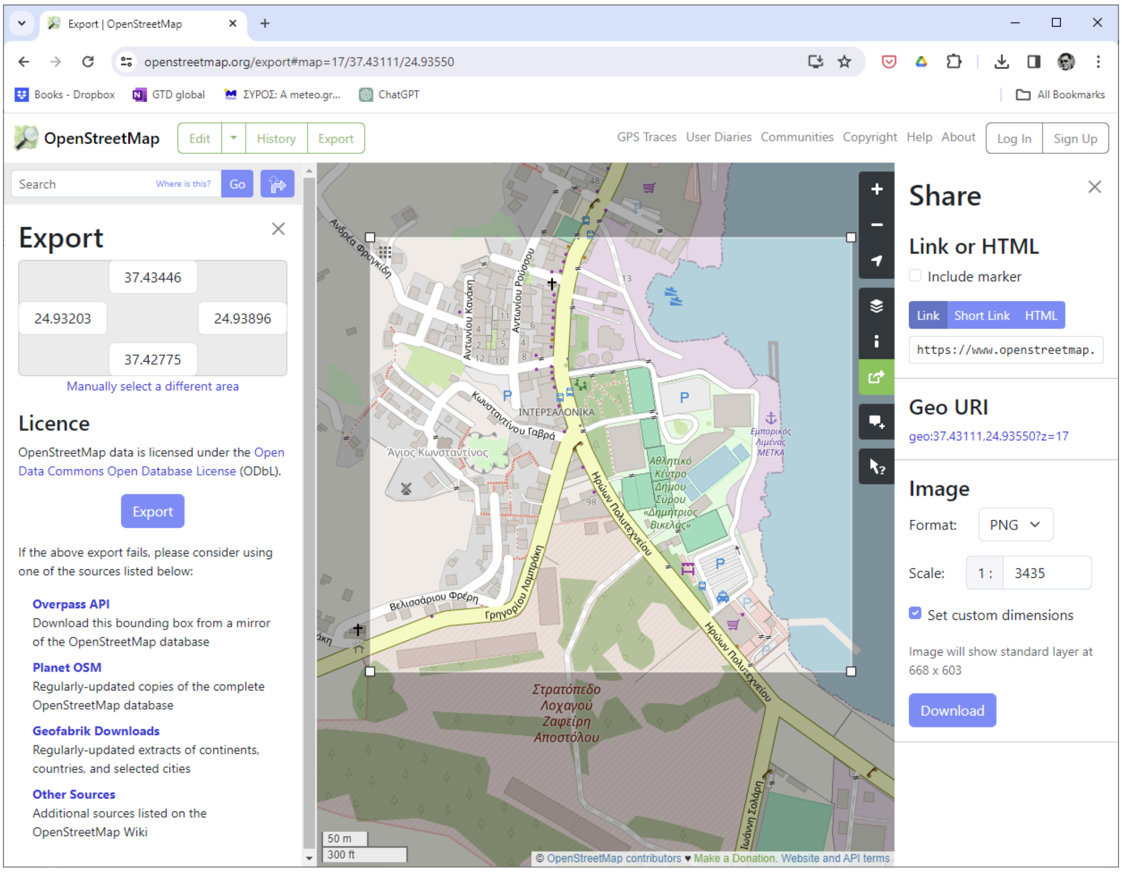


Image 22: Click on the “Set custom dimensions” tick-box.

4. Under the “Export” Menu, click the “Manually select a different area” button. A second area setting box will appear. Place the second box so that it fits directly on top of the first one.

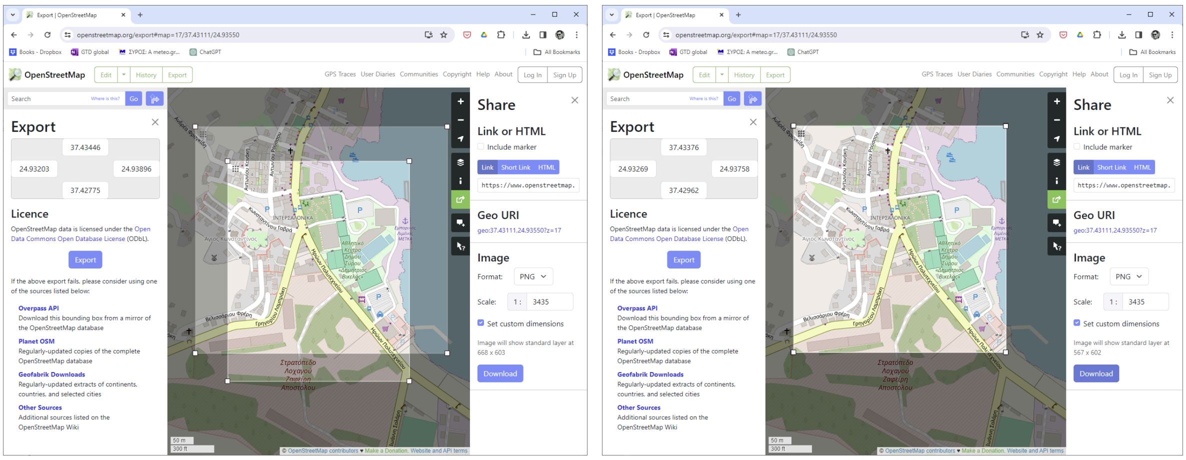
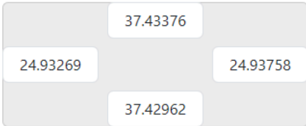


Image 23: The second area setting box is on top of the first one.

5. Click the “Export” button, and save the image as: “map.png” (name: map, file type: png).
6. Copy, or write down the four GPS values displayed on the top-left box under Export:

(top, left): 37.43376, 24.93269
(bottom, right): 37.42962, 24.93758

top

left  right

Bottom

Image 24: Coordinates in the top-left box under Export.

7. Open the configuration file (config.txt) and paste the saved values on the variables:
   map_top_left = 37.43376, 24.93269
   map_bottom_right = 37.42962, 24.93758
8. Save and exit the configuration file.

In this way, you created the map image and inserted the necessary values in the configuration file, so that the map screen would be displayed properly in the Usersence Visualization App. The next section presents how to organize the necessary files and folders in order to run the Usersence Command Line Application and the Visualization App correctly.

Folder Structure System

The sequence between the Command Line Application and the Visualization App is predefined and can not be altered, because the first application, if organized properly, analyzes the data, and the second one visualizes them, generating the experience chart. Before running the applications, it is mandatory to collect all the necessary files mentioned above and move them to a specific location on your computer with a certain structure. Follow the instructions to create your working directory.

1. Go to your File Explorer and choose the location to create a Folder.
   a. Suggested location: Documents Folder on your computer.
2. Create a New Folder and name it “HeritACT”.
   a. This is the Folder where all the evaluation sessions must be transferred.
3. Inside the “HeritACT” Folder, create a New Folder with the name “EvaluationHermoupolis”.
   a. This is the Folder where all session-gathered data must be transferred per user.
4. In the “EvaluationHermoupolis” Folder insert the configuration file (config.txt) and the map image (map.png) you created.
5. In the “EvaluationHermoupolis” Folder, create a New Folder and name it “userID”.

    a. This is the Folder where all the data of a single participant must be transferred.
    b. Do not name the “userID” Folder with a real name.
    c. To insert more participants in the “EvaluationHermoupolis” Folder session, create New Folders with different user ID names, for example, the next participant's Folder should be named “userIDnext”.
6. In the “userID” Folder, create five (5) New Folders:
    a. “E4” Folder
    b. “MobileApp” Folder
    c. “Webcam” Folder
    d. “Action Camera” Folder
    e. “EmotivHeadset” Folder
7. Move to the “E4” Folder the files:
    a. EDA.csv
    b. IBI.csv
    c. tags.csv
8. Move to the “MobileApp” Folder the following files and delete their numeric extension (do not use path1.csv or responses1.csv):
    a. path.csv
    b. responses.csv
9. Move to the “Webcam” Folder:
    a. faceVideo.mp4
10. Move to the “Action Camera” Folder:
    a. videoRecording.mp4
11. Move to the “EmotivHeadset” Folder:
    a. eeg.csv

Note:

- Create the Folder Structure either the evaluation is conducted in the field or lab.
- Leave empty the Folder for which you have no data.
- You can copy and paste the folder structure which is included as the Experiment Folder template.

Examples of a working directory with the mandatory Folder structure are illustrated in the following images. In the first example, instead of the Documents Folder, the Projects Folder is selected, and the “EvaluationHermoupolis” Folder has been renamed to “testexp”, which includes four participants' Folders with different IDs.

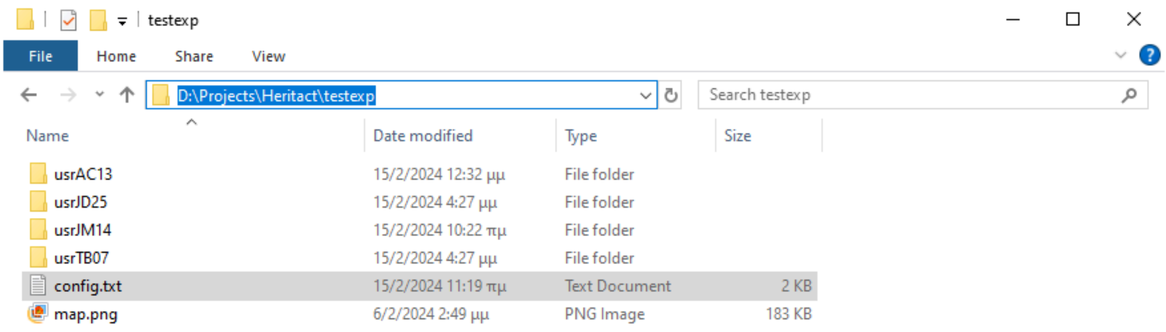


Image 25: Working directory example with the mandatory Folder structure.

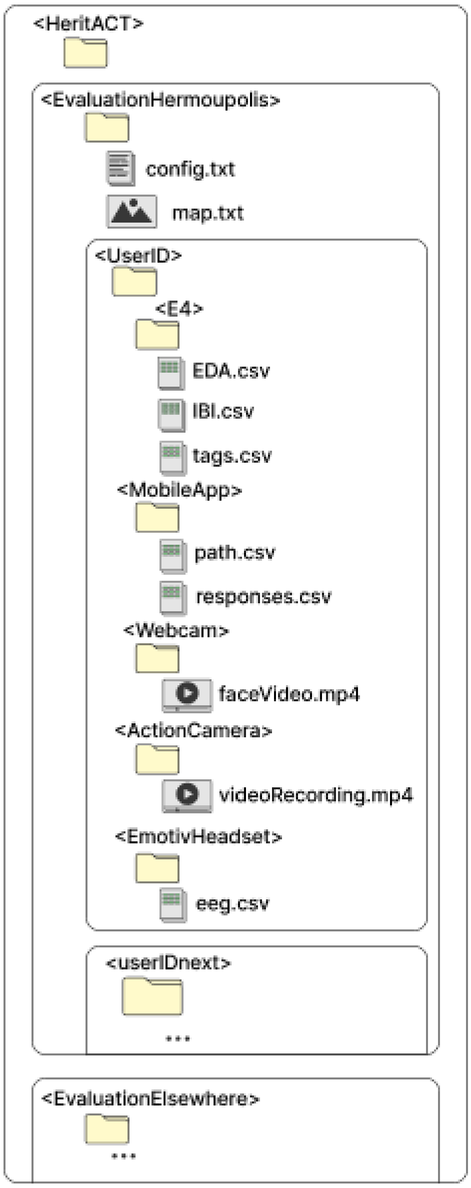


Image 26: Folder Structure System Diagram.

Command Line Application

The data analysis is conducted with the assistance of the Command Prompt or the Command-Line Interpreter. Firstly, ensure that the configuration file, the config.txt in the Usersence Folder you downloaded from the tool's repository, is ready to use and if a customization is needed, make any change necessery before continuing on the next steps. The default settings for data analysis are:

- eda_thres=0.7
- eda_offset=1.0
- eda_start_wt=4
- eda_end_wt=4
- ibi_window_size=120
- facecam_freq=2

When you are ready:

1. Open the Command Prompt by searching "cmd" on your taskbar.

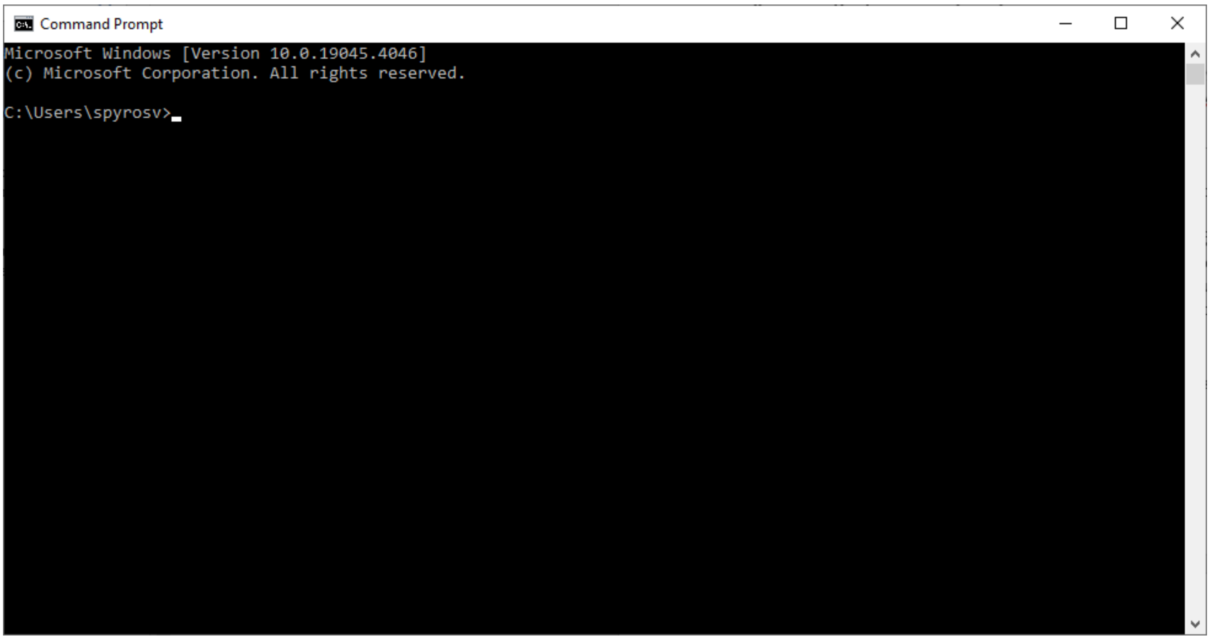


Image 27:Open the Command Prompt.

HeritACT The project has received funding from
HORIZON-CL2-2022-HERITAGE-01
under Grant Agreement Number 101094998

2. Navigate to the Analysis Folder.

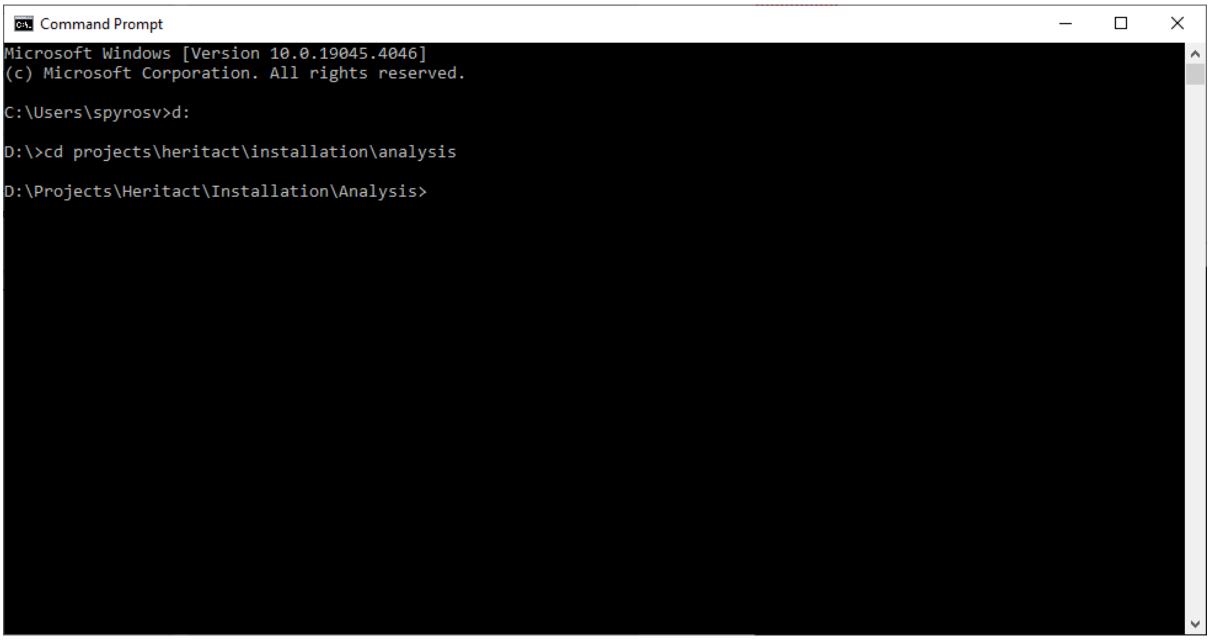


Image 28:Navigate to the Analisi Folder.

3. Insert the path of the session’s Folder (e.g. EvaluationHermoupolis or testexp) by typing analysis (hit space) (pase the folder path)! Then press the “ENTER” button.

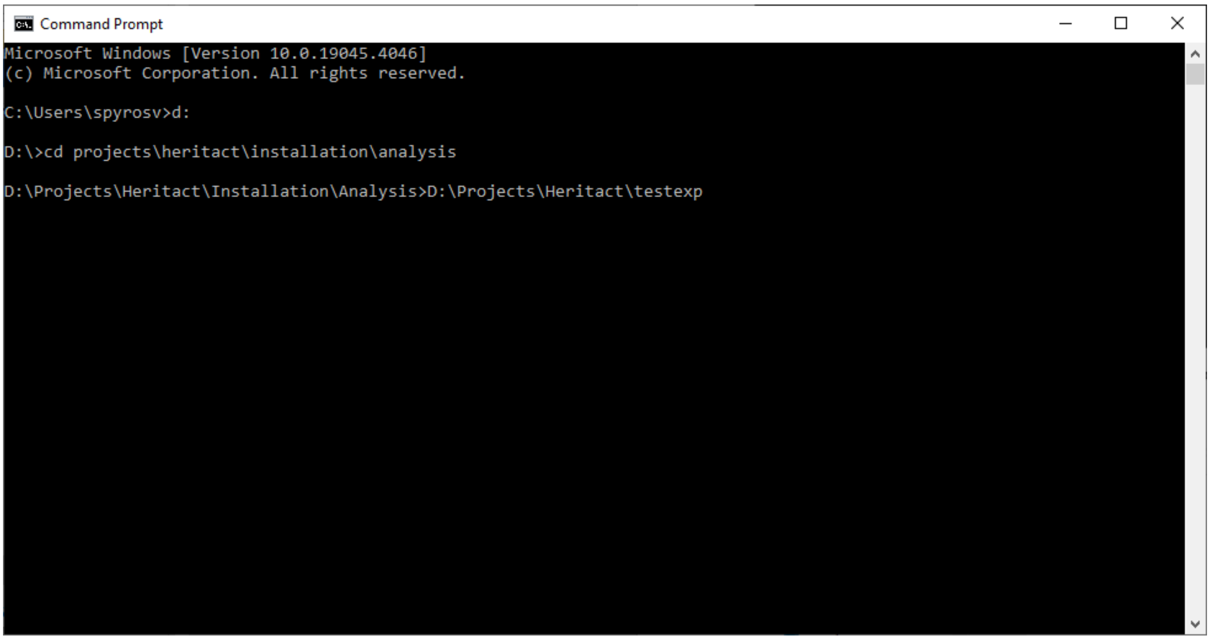


Image 29:Insert your session’s Folder.

4. Wait until the analysis is performed for each user-folder.

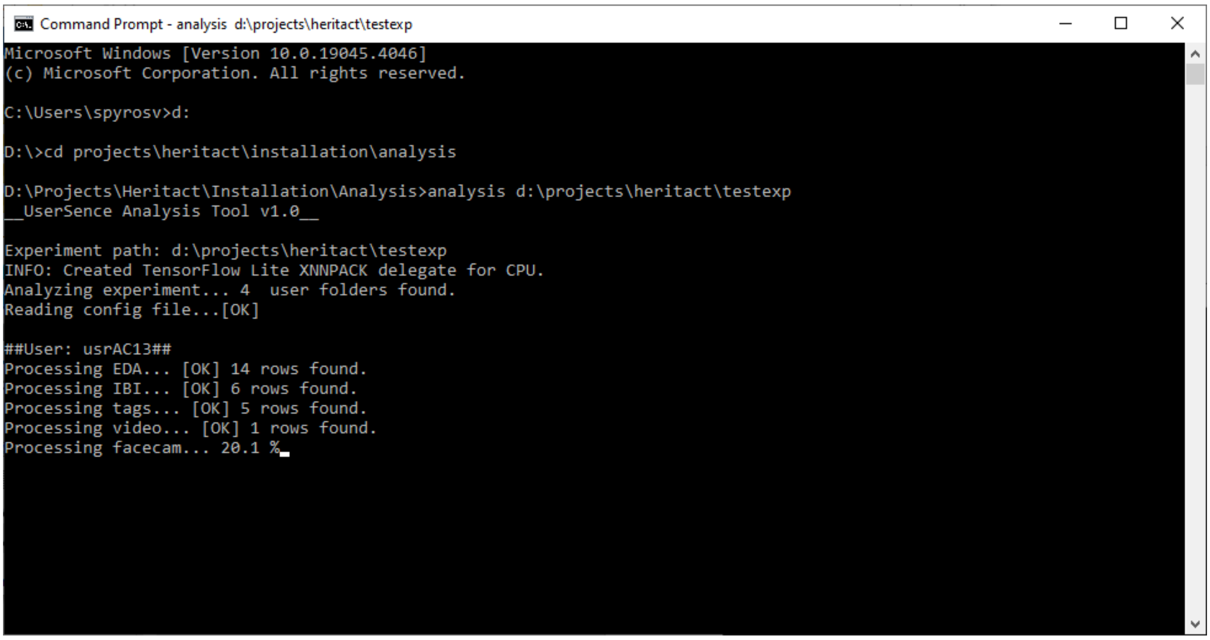


Image 30:Data Analys in the Command Line Application.

Note: When the analysis is completed (100%) then open the Usersence Visualization Application (SensViz.exe).

Visualization Application

The evaluator should launch the Usersence Visualization Application, only when they have completed all the previous steps which include the data recording and exporting from the involved devices, the mandatory creation of the folder structure and the placement of the needed files in it, and the launch of the Command Line Application. Switching the sequence of steps will cause undesirable results because the system will not work properly and no experience chart will be created.

Firstly, before opening the Usersence Visualization Application, find and copy the file path of your Folder (e.g. EvaluationHermoupolis or testexp based on the previous examples), which contains the files of an evaluation organized by each participant. If the path is not visible as in the picture below then:

1. Right-click on the “testexp ” Folder.
2. Click on the “Properties” option.
3. Copy the path from Location in the General Menu on the pop-up window.

The copied path according to the example is: “D:\Projects\Heritact\testexp”. The example refers to a field evaluation with four users, utilizing the E4 wristband, the smartphone, and thus the Usersence Mobile App and the Action Camera.

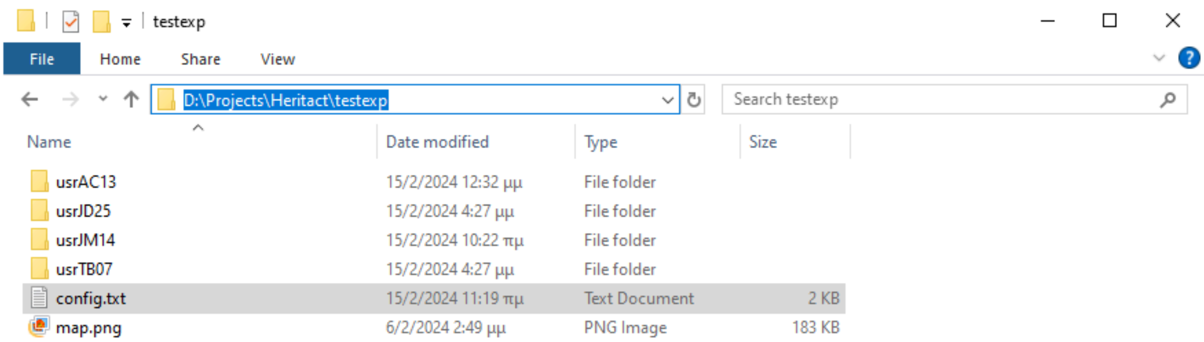


Image 31: Find Folder path.

Subsequently, open the Usersence Visualization App by double-clicking the file located in the Usersence Folder you downloaded from the tool's repository. Once the window appears, paste the path in the edit box on the top-left corner, near the Exp. path, and click the "update" button.

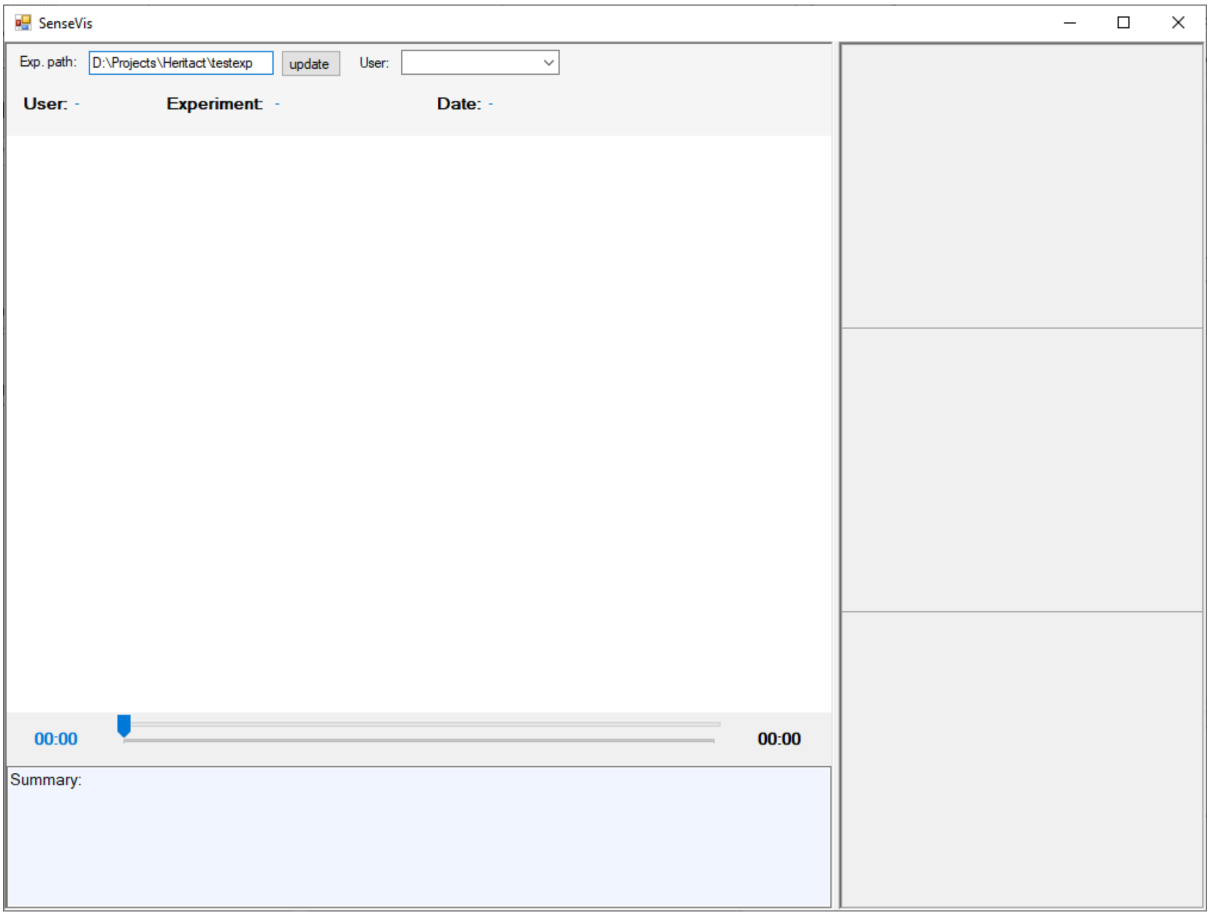


Image 32: Paste the Folder path.

As a result, the name of the experiment (as declared in the config.txt) and the map image (if added) are displayed. Also, on the Combobox near User, the total number of participants, whose data analysis has already been completed, is presented.

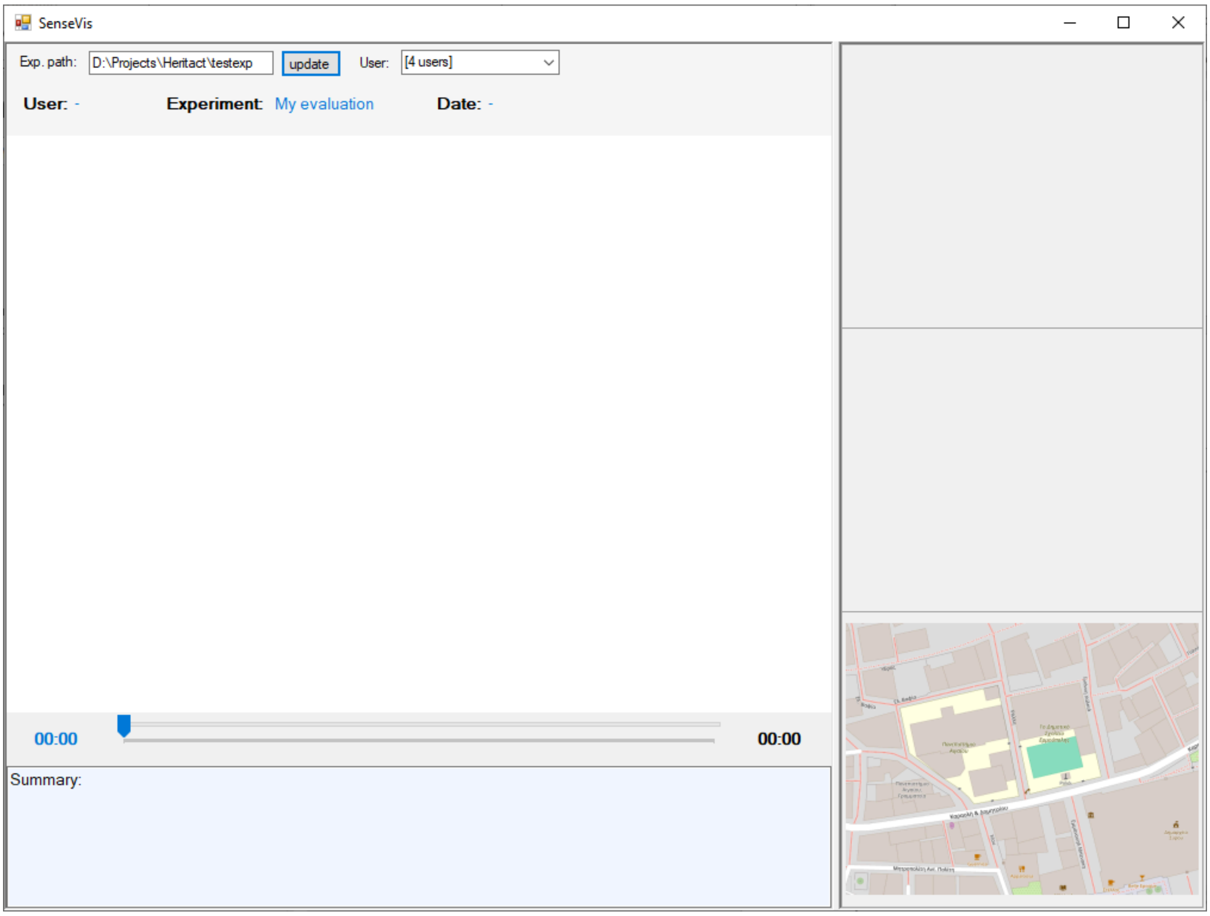


Image 33: Update data to the Visualization App.

To generate the Experience Chart for each participant, click on the Combobox, and select an option from the drop-down list.

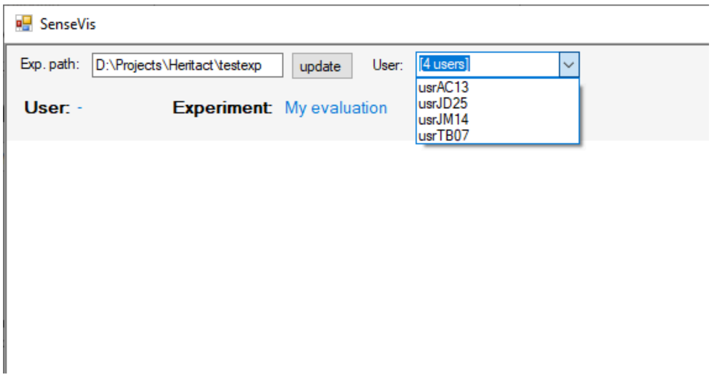


Image 34: Participants on the Combobox drop-down list.

The user's selection will generate the interactive presentation of the user's experience chart. The name of the user's file, the date, and the time are displayed at the top of the chart. At the same time, in the center of the window, a series of Lanes are presenting the analyzed data that the evaluator imported into the Folder Structure. To the left of each Lane is the data source, while on the right is the data interpretation.

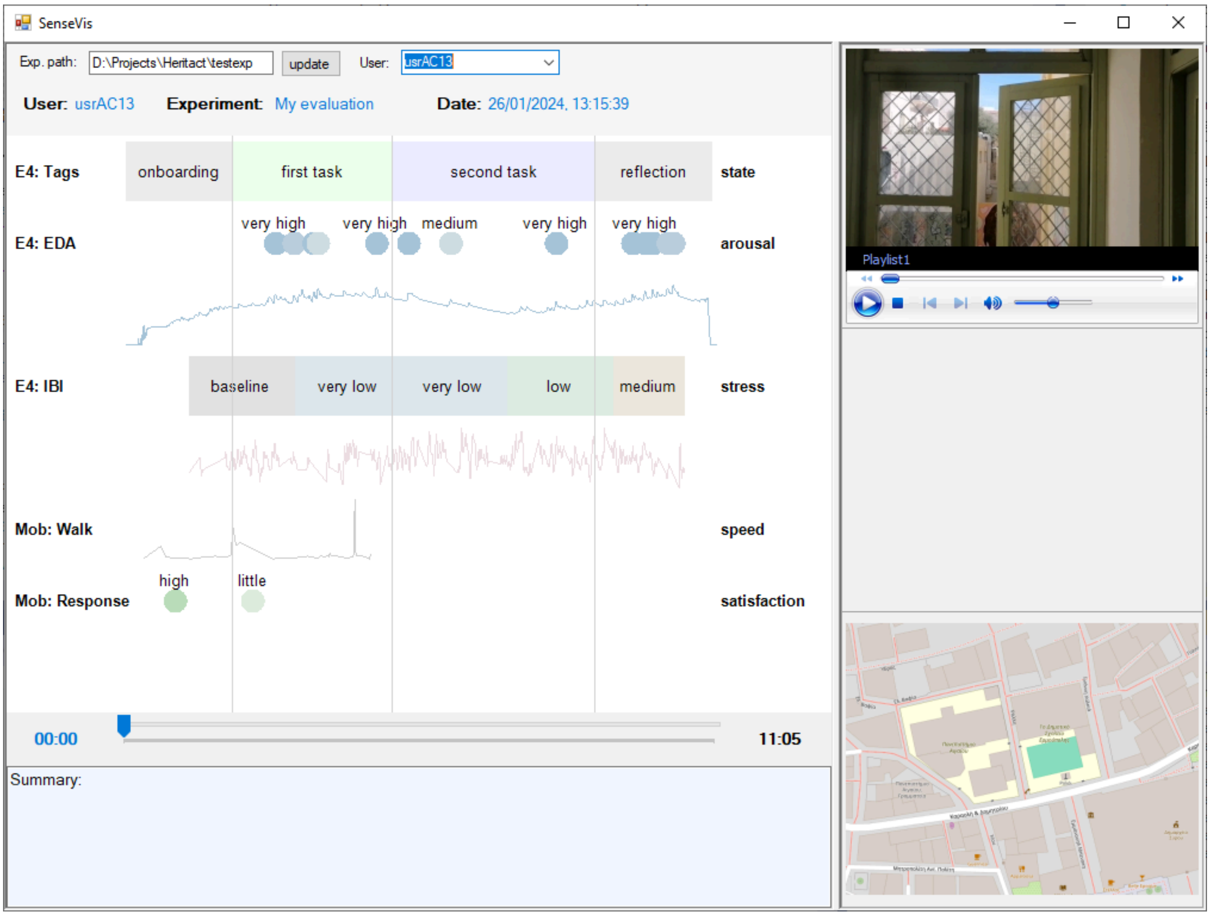


Image 35: Experience Chart of the participant usrAC13.

The Usersence Experience Chart depicts the following aspects of the User Experience, based on the devices and software utilized in the previous steps:

- **E4: Tags**
  Based on the time stamps when the tag button was pressed and based on the names given in config.txt (see tag_values) the states were created (in config.txt: tag_type = state). If tag_type was declared as "event" they would be painted as instant points.
- **E4: EDA**
  EDA Peaks (arousal) colored and categorized according to their intensity. The distinction between medium, high, and very high is made by the associated settings in config.txt (eda_high_perc, eda_very_high_perc). Below, the raw

data is painted as a graph. The color of the graph, labels, and their colors are set in config.txt (eda_graph_color, eda_values)

- **E4: IBI**
  The analysis of the IBI in "windows" displays stress in relation to the baseline. The size of the window in seconds is in config.txt (ibi_window_size) and is used in the analysis. The distinctions between high/very high and respectively low/very low stress are made by the relevant settings in config.txt (ibi_high_perc, ibi_very_high_perc). Below that the raw data is drawn as a graph. The color of the graph, labels, and their colors are set in config.txt (ibi_graph_color, ibi_values).
- **Mob: Walk**
  The user's movement speed graph.
- **GPS**
  Its color is declared in config.txt (gps_graph_color).
- **Mob: Response**
  The participant's questionnaire answers from the mobile phone - Usersence Mobile App. The response type is given in config.txt (response_type) and is written to the right of the lane. The labels and colors (for answers from 1 to 5 - Likert Scale) are given in config.txt (response_values).

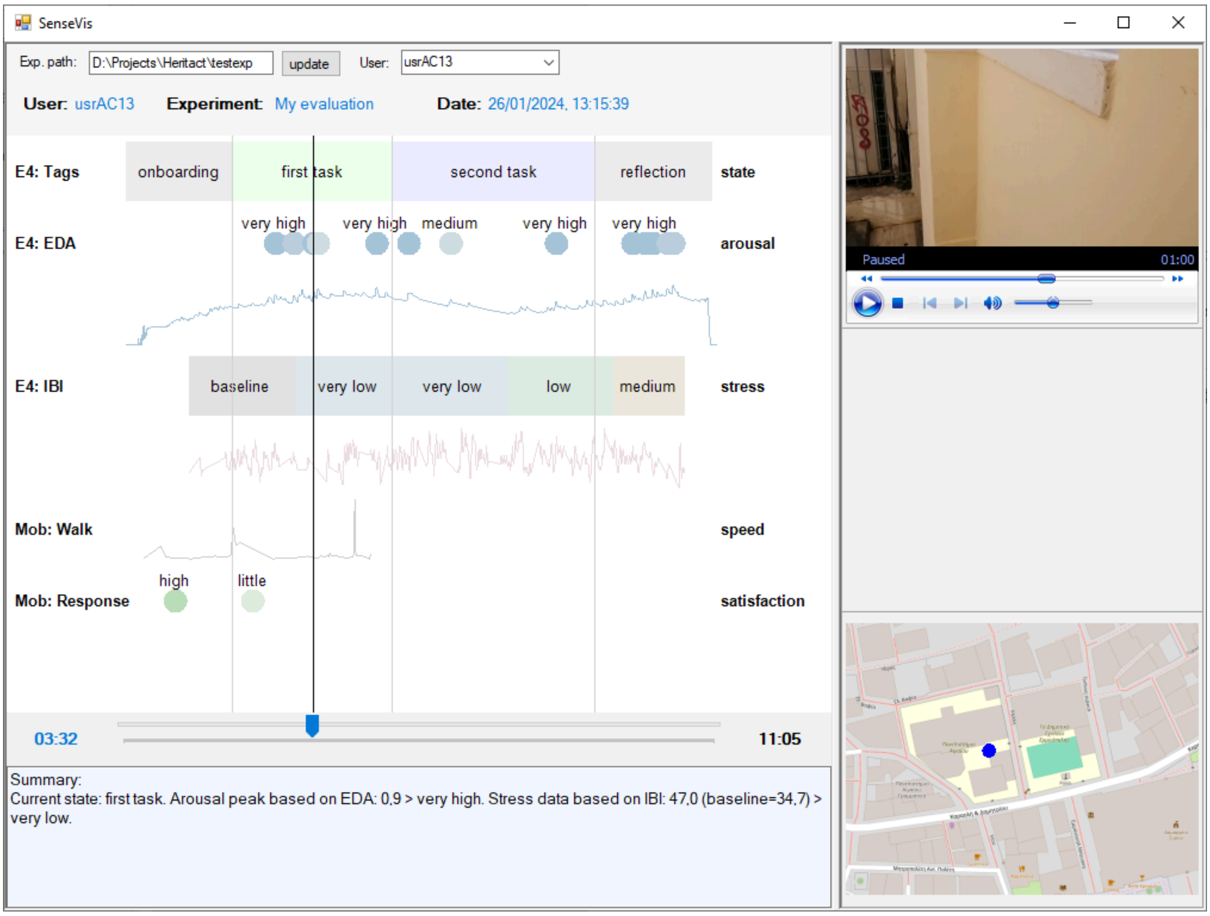


Image 36: Interact with the Experience Chart.

Interact with the Experience Chart by moving the timeline. The blue time indication corresponds to the time point in seconds, while on the right side of the timeline, the full session duration is displayed. The timeline movement affects the smaller screens of the chart, as the timeline of the recorded video (footage from the action camera, on the top right screen) and the participant's route (based on the Location/GPS of the smartphone and the Mobile App, on the bottom right screen) changes accordingly and simultaneously. Finally, a short summary of the findings per timestamp is printed in the lower blue window.

References

Albert, B., & Tullis, T. (2022). *Measuring the User Experience: Collecting, Analyzing, and Presenting UX Metrics*. Morgan Kaufmann.

Bota, P. J., Wang, C., Fred, A. L. N., & Plácido Da Silva, H. (2019). A Review, Current Challenges, and Future Possibilities on Emotion Recognition Using Machine Learning and Physiological Signals. *IEEE Access*, *7*, 140990–141020. https://doi.org/10.1109/ACCESS.2019.2944001

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, *25*(1), 49–59. https://doi.org/10.1016/0005-7916(94)90063-9

Bulagang, A. F., Mountstephens, J., & Wi, J. T. T. (2020). Tuning Support Vector Machines for Improving Four-Class Emotion Classification in Virtual Reality (VR) using Heart Rate Features. *Journal of Physics: Conference Series*, *1529*(5), 052069. https://doi.org/10.1088/1742-6596/1529/5/052069

Calvo, R. A., & D'Mello, S. (2010). Affect Detection: An Interdisciplinary Review of Models, Methods, and Their Applications. *IEEE Transactions on Affective Computing*, *1*(1), 18–37. https://doi.org/10.1109/T-AFFC.2010.1

Castaneda, D., Esparza, A., Ghamari, M., Soltanpur, C., & Nazeran, H. (2018). A review on wearable photoplethysmography sensors and their potential future applications in health care. *International Journal of Biosensors & Bioelectronics*, *4*(4), 195–202. https://doi.org/10.15406/ijbsbe.2018.04.00125

Choi, E. J., & Kim, D. K. (2018). Arousal and Valence Classification Model Based on Long Short-Term

Memory and DEAP Data for Mental Healthcare Management. *Healthcare Informatics Research*, *24*(4), 309–316. https://doi.org/10.4258/hir.2018.24.4.309

Cittadini, R., Tamantini, C., Scotto di Luzio, F., Lauretti, C., Zollo, L., & Cordella, F. (2023). Affective state estimation based on Russell's model and physiological measurements. *Scientific Reports*, *13*(1), Article 1. https://doi.org/10.1038/s41598-023-36915-6

Cosoli, G., Poli, A., Scalise, L., & Spinsante, S. (2021). Measurement of multimodal physiological signals for stimulation detection by wearable devices. *Measurement*, *184*, 109966. https://doi.org/10.1016/j.measurement.2021.109966

Doma, V., & Pirouz, M. (2020). A comparative analysis of machine learning methods for emotion recognition using EEG and peripheral physiological signals. *Journal of Big Data*, *7*(1), 18. https://doi.org/10.1186/s40537-020-00289-7

Domínguez-Jiménez, J. A., Campo-Landines, K. C., Martínez-Santos, J. C., Delahoz, E. J., & Contreras-Ortiz, S. H. (2020). A machine learning model for emotion recognition from physiological signals. *Biomedical Signal Processing and Control*, *55*, 101646. https://doi.org/10.1016/j.bspc.2019.101646

Douglas, I. (2012). Urban ecology and urban ecosystems: Understanding the links to human health and well-being. *Current Opinion in Environmental Sustainability*, *4*(4), 385–392. https://doi.org/10.1016/j.cosust.2012.07.005

E4 wristband | Real-time physiological signals | Wearable PPG, EDA, Temperature, Motion sensors. (n.d.). Empatica. Retrieved March 15, 2023, from https://www.empatica.com/research/e4

Egger, M., Ley, M., & Hanke, S. (2019). Emotion Recognition from Physiological Signal Analysis: A Review. *Electronic Notes in Theoretical Computer Science*, *343*, 35–55. https://doi.org/10.1016/j.entcs.2019.04.009

EPOC Flex. (n.d.). EMOTIV. Retrieved March 15, 2023, from https://www.emotiv.com/epoc-flex/

Experience, W. L. in R.-B. U. (n.d.). *The Definition of User Experience (UX)*. Nielsen Norman Group. Retrieved February 16, 2024, from https://www.nngroup.com/articles/definition-user-experience/

Garbarino, M., Lai, M., Bender, D., Picard, R. W., & Tognetti, S. (2014). Empatica E3—A wearable wireless multi-sensor device for real-time computerized biofeedback and data acquisition. *2014 4th International Conference on Wireless Mobile Communication and Healthcare - Transforming*

Healthcare Through Innovations in Mobile and Wireless Technologies (MOBIHEALTH), 39–42. https://doi.org/10.1109/MOBIHEALTH.2014.7015904

Geršak, G. (2020). Electrodermal activity—A beginner's guide. *Electrotechnical Review / Elektrotehniski Vestnik*.

GoPro MAX 360 Action Camera (Waterproof + Stabilization). (n.d.). Retrieved February 16, 2024, from https://gopro.com/en/gr/shop/cameras/max/CHDHZ-202-master.html

Guite, H. F., Clark, C., & Ackrill, G. (2006). The impact of the physical and urban environment on mental well-being. *Public Health*, *120*(12), 1117–1126. https://doi.org/10.1016/j.puhe.2006.10.005

Hickey, B. A., Chalmers, T., Newton, P., Lin, C.-T., Sibbritt, D., McLachlan, C. S., Clifton-Bligh, R., Morley, J., & Lal, S. (2021). Smart Devices and Wearable Technologies to Detect and Monitor Mental Health Conditions and Stress: A Systematic Review. *Sensors*, *21*(10), Article 10. https://doi.org/10.3390/s21103461

Horvers, A., Tombeng, N., Bosse, T., Lazonder, A. W., & Molenaar, I. (2021). Detecting Emotions through Electrodermal Activity in Learning Contexts: A Systematic Review. *Sensors*, *21*(23), Article 23. https://doi.org/10.3390/s21237869

ISO. (2010). *Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems (ISO 9241-210:2010)*. https://www.iso.org/obp/ui/#iso:std:iso:9241:-210:ed-1:v1:en

Jain, A. K., Ross, A. A., & Nandakumar, K. (2011). *Introduction to Biometrics*. Springer Science & Business Media.

Kim, K. B., & Baek, H. J. (2023). Photoplethysmography in Wearable Devices: A Comprehensive Review of Technological Advances, Current Challenges, and Future Directions. *Electronics*, *12*(13), Article 13. https://doi.org/10.3390/electronics12132923

Logitech C615 Full HD Webcam. (n.d.). Retrieved February 16, 2024, from https://www.logitech.com/en-us/products/webcams/c615-webcam.html

Lugaresi, C., Tang, J., Nash, H., McClanahan, C., Uboweja, E., Hays, M., Zhang, F., Chang, C.-L., Guang Yong, M., Lee, J., Chang, W.-T., Hua, W., Georg, M., & Grundmann, M. (2019). *MediaPipe: A Framework for Perceiving and Processing Reality*. Google Research.

Lugaresi, C., Tang, J., Nash, H., McClanahan, C., Uboweja, E., Hays, M., Zhang, F., Chang, C.-L., Yong, M. G., Lee, J., Chang, W.-T., Hua, W., Georg, M., & Grundmann, M. (2019). *MediaPipe: A Framework for Building Perception Pipelines* (arXiv:1906.08172). arXiv.

https://doi.org/10.48550/arXiv.1906.08172

Maia, C. L. B., & Furtado, E. S. (2016). A Systematic Review About User Experience Evaluation. In A. Marcus (Ed.), *Design, User Experience, and Usability: Design Thinking and Methods* (pp. 445–455). Springer International Publishing. https://doi.org/10.1007/978-3-319-40409-7_42

Malhi, G. S., Hamilton, A., Morris, G., Mannie, Z., Das, P., & Outhred, T. (2017). The promise of digital mood tracking technologies: Are we heading on the right track? *BMJ Ment Health*, *20*(4), 102–107. https://doi.org/10.1136/eb-2017-102757

MediaPipe. (n.d.). Google for Developers. Retrieved February 16, 2024, from https://developers.google.com/mediapipe

Mortensen, C. D. (Ed.). (2017). *Communication Theory* (2nd ed.). Routledge. https://doi.org/10.4324/9781315080918

Posada-Quintero, H. F., & Chon, K. H. (2020). Innovations in Electrodermal Activity Data Collection and Signal Processing: A Systematic Review. *Sensors (Basel, Switzerland)*, *20*(2), 479. https://doi.org/10.3390/s20020479

Ragot, M., Martin, N., Em, S., Pallamin, N., & Diverrez, J.-M. (2018). Emotion Recognition Using Physiological Signals: Laboratory vs. Wearable Sensors. In T. Ahram & C. Falcão (Eds.), *Advances in Human Factors in Wearable Technologies and Game Design* (pp. 15–22). Springer International Publishing. https://doi.org/10.1007/978-3-319-60639-2_2

Roy, J.-C., Boucsein, W., Fowles, D. C., & Gruzelier, J. (2012). *Progress in Electrodermal Research*. Springer Science & Business Media.

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, *39*(6), 1161–1178. https://doi.org/10.1037/h0077714

Saganowski, S., Dutkowiak, A., Dziadek, A., Dzieżyc, M., Komoszyńska, J., Michalska, W., Polak, A., Ujma, M., & Kazienko, P. (2020). Emotion Recognition Using Wearables: A Systematic Literature Review - Work-in-progress. *2020 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)*, 1–6. https://doi.org/10.1109/PerComWorkshops48775.2020.9156096

Savin, A. V., Sablina, V. A., & Nikiforov, M. B. (2021). Comparison of Facial Landmark Detection Methods for Micro-Expressions Analysis. *2021 10th Mediterranean Conference on Embedded Computing (MECO)*, 1–4. https://doi.org/10.1109/MECO52532.2021.9460191

Sayed Ismail, S. N. M., Ab. Aziz, N. A., & Ibrahim, S. Z. (2022). A comparison of emotion recognition system using electrocardiogram (ECG) and photoplethysmogram (PPG). *Journal of King Saud University - Computer and Information Sciences*, *34*(6, Part B), 3539–3558. https://doi.org/10.1016/j.jksuci.2022.04.012

Schmidt, P., Reiss, A., Dürichen, R., & Laerhoven, K. V. (2019). Wearable-Based Affect Recognition—A Review. *Sensors*, *19*(19), Article 19. https://doi.org/10.3390/s19194079

Shaffer, F., & Ginsberg, J. P. (2017). An Overview of Heart Rate Variability Metrics and Norms. *Frontiers in Public Health*, *5*. https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2017.00258

Siam, A. I., Soliman, N. F., Algarni, A. D., Abd El-Samie, F. E., & Sedik, A. (2022). Deploying Machine Learning Techniques for Human Emotion Detection. *Computational Intelligence and Neuroscience*, *2022*, e8032673. https://doi.org/10.1155/2022/8032673

Soufineyestani, M., Dowling, D., & Khan, A. (2020). Electroencephalography (EEG) Technology Applications and Available Devices. *Applied Sciences*, *10*(21), Article 21. https://doi.org/10.3390/app10217453

Subramanian, B., Kim, J., Maray, M., & Paul, A. (2022). Digital Twin Model: A Real-Time Emotion Recognition System for Personalized Healthcare. *IEEE Access*, *10*, 81155–81165. https://doi.org/10.1109/ACCESS.2022.3193941

Taherdoost, H. (2019). *What Is the Best Response Scale for Survey and Questionnaire Design; Review of Different Lengths of Rating Scale / Attitude Scale / Likert Scale* (SSRN Scholarly Paper 3588604). https://papers.ssrn.com/abstract=3588604

Taylor, S., Jaques, N., Chen, W., Fedor, S., Sano, A., & Picard, R. (2015). Automatic identification of artifacts in electrodermal activity data. *2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 1934–1937. https://doi.org/10.1109/EMBC.2015.7318762

Thayer, J. F. (2017). A neurovisceral integration model of heart rate variability.

Udovičić, G., Đerek, J., Russo, M., & Sikora, M. (2017). Wearable Emotion Recognition System based on GSR and PPG Signals. *Proceedings of the 2nd International Workshop on Multimedia for Personal Health and Health Care*, 53–59. https://doi.org/10.1145/3132635.3132641

Veeranki, Y. R., Ganapathy, N., & Swaminathan, R. (2021). Electrodermal Activity Based Emotion

Recognition using Time-Frequency Methods and Machine Learning Algorithms. *Current Directions in Biomedical Engineering*, *7*(2), 863–866. https://doi.org/10.1515/cdbme-2021-2220

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070. https://doi.org/10.1037/0022-3514.54.6.1063

Waxenbaum JA, Reddy V, Varacallo M. Anatomy, Autonomic Nervous System. In: StatPearls. StatPearls Publishing, Treasure Island (FL); 2023. PMID: 30969667.

Wiem, M. B. H., & Lachiri, L. (2017). Emotion Classification in Arousal Valence Model using MAHNOB-HCI Database. *International Journal of Advanced Computer Science and Applications*. https://www.semanticscholar.org/paper/Emotion-Classification-in-Arousal-Valence-Model-Wiem-Lachiri/3750b635d455fee489305b24ead4b7e9233b7209

Zhang, F., Bazarevsky, V., Vakunov, A., Tkachenka, A., Sung, G., Chang, C.-L., & Grundmann, M. (2020). *MediaPipe Hands: On-device Real-time Hand Tracking* (arXiv:2006.10214). arXiv. https://doi.org/10.48550/arXiv.2006.10214

Zhang, J., Yin, Z., Chen, P., & Nichele, S. (2020). Emotion recognition using multi-modal data and machine learning techniques: A tutorial and review. *Information Fusion*, *59*, 103–126. https://doi.org/10.1016/j.inffus.2020.01.011

ΠΡΟΔΙΑΓΡΑΦΕΣ | Galaxy S21 Ultra, S21 Plus & S21 5G | Samsung Greece. (n.d.). Samsung gr. Retrieved February 16, 2024, from https://www.samsung.com/gr/smartphones/galaxy-s21-ultra-5g/specs/