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Designing a tool for measuring welfare parameters(May 2025)

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*Abstract*— Employee wellness is ever more recognized as a vital factor in workplace productivity and job satisfaction, yet low-cost and accessible solutions for monitoring health metrics are limited. The article details the design and implementation of a low-cost and portable real-time measuring device for important physiological parameters like heart rate, blood oxygen level (SpO₂), galvanic skin response (GSR), and respiration rate by using an Arduino Nano ESP32 microcontroller. The system employs calibrated sensors and transmits data in Bluetooth Low Energy to a custom mobile application, which includes user-friendly graphical visualizations and multi-user capability for organizational deployment. Design focuses on usability, accessibility, and flexibility, with baseline calibration and color-coded feedback to facilitate interpretation by non-specialists. In contrast to commercial solutions, this open and extensible toolkit provides a transparent and affordable approach to workplace well-being monitoring. The program establishes a basis for more general use of physiological health assement and is a stepping-stone for follow-on research and development in occupational health technology.

*Index Terms*—Health metrics, mobile application, portable devices, physiological sensors, workplace well-being

# INTRODUCTION (NEED TO IMPROVE)

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n today's workplace, employee well-being is becoming a significant part of productivity and job satisfaction. Stress is one of the leading causes of work discomfort and can have negative impacts on physical and mental health. Therefore, the ability to measure and monitor stress-related physiological parameters effectively plays a critical role in creating a healthier workplace.

This thesis explores the development of a small and portable device for monitoring a person's well-being while performing work activity. There are commercial alternatives like smartwatches, but they are expensive, not widely accessible, or not transparent in their operation. An inexpensive and versatile solution is therefore necessary. This project entails the construction of a well-being toolkit based on Arduino technology, with emphasis on determining the physiological parameters best suited to monitor stress or general well-being, including heart rate and skin conductance.

The aim of this project is to create and implement a system that not only collects data but also presents it in a useful format through a dedicated application. The application will enable users to monitor their well-being real-time by measuring relevant physiological parameters such as heart rate and skin conductance. The hardware and software in this project are designed to provide a user friendly tool for measuring workplace well-being.

To achieve this, the research first explored relevant sensor technologies used to measure stress. This is followed by developing a system architecture that would ensure seamless communication between the sensors and Arduino and data processing and visualization in the app.

By providing a low-cost and user-friendly solution to stress monitoring, the project aims to be a contributor to the new wave of workplace well-being technology and a foundation for more data-based solutions for managing stress.

# Related work (NEED TO ADD)

## Stress Detection using Galvanic Skin Response: An Android Application (<https://iopscience.iop.org/article/10.1088/1742-6596/1372/1/012001/meta>)

Navea et al. (2019) presented an Android application that uses GSR for detecting stress levels when mobile texting. The application measures skin conductance, reflecting sweat gland activity regulated by the sympathetic nervous system. They found extremely minimal stress across texting sessions with no noteworthy effects of phone model or session length. The results of the application were similar to those achieved by utilizing the commercially produced eSense GSR device, thus proving its effectiveness in real-time stress measurement. While the study focused mainly on stress levels while using mobile phones, it highlights the potential of GSR-enabled mobile apps as convenient and affordable tools for tracking emotional states. In contrast, this thesis extends the application range by integrating different physiological sensors into a generalized, low-cost user friendly system for more extensive use in workplace and daily environments, even for non-expert users.

## Stress detection in daily life scenarios using smartphones and wearable sensors: A survey (<https://www.sciencedirect.com/science/article/pii/S1532046419300577>)

Recent developments in stress detection using smartphones and wearable sensors have enabled the measurement of stress in daily life, beyond the controlled laboratory environment. Arnrich and Cem (2019) report the incorporation of physiological sensors such as heart rate and electrodermal activity (GSR) with contextual information obtained from smartphones (e.g., location and usage patterns). They point out that the fusion of these different kinds of data renders the stress detection models not only more accurate but also more robust under realistic, everyday conditions.

The survey also touches on machine learning for stress detection automatically, with the note that both personalized models and multimodal data fusion are essential in handling individual variability in stress reaction. Challenges in translating laboratory-based techniques to daily life, such as sensor noise and user compliance, are noted by the authors, who stress the need for unobtrusive and easy-to-use systems.

This work presents a multi-sensor system integrating heart rate, GSR, blood oxygen saturation, and respiration rate into one low-cost device with an accompanying multi-user, user-friendly application. The system supports real-time and retrospective monitoring, subject-specific calibration, and emphasizes clean data visualization and education, making stress monitoring more accessible and understandable in the workplace.

## A Critical Review of Consumer Wearables, Mobile Applications, and Equipment for Providing Biofeedback, Monitoring Stress, and Sleep in Physically Active Populations (<https://www.frontiersin.org/journals/physiology/articles/10.3389/fphys.2018.00743/full>)

Peake et al. (2018) undertook a critical review of consumer-worn technologies and mobile applications aimed at the measurement of biofeedback, stress, and sleep in physically active groups. The review analyzed more than 70 commercially available technologies based on their purported functions, validation procedures, reliability, and consumer appropriateness. The result was that merely 5% of the technologies had been independently validated, whereas more than half had not received any scientific review at all. The authors stress the need to match technological advancements with practical requirements and refer to the drawbacks of most existing solutions, such as high expense, lack of verification, and complexity in data interpretation without expertise. These observations support the motivation of this thesis, which is to offer a more affordable and cost-effective health-monitoring tool based on physiological sensors and an effective and clear user interface.

# Methods and materials

## This section describes the hardware configuration and software architecture of the wearable health measurement system. The system is built around an ESP32 microcontroller and incorporates multiple physiological sensors to capture heart rate, blood oxygen saturation (SpO₂), GSR, and respiratory activity. The sensor data is processed locally and transmitted via Bluetooth Low Energy (BLE) to a mobile application for visualization and analysis.

## Arduino Nano ESP32

The stress measuring device is powered by an Arduino Nano ESP32 which is based on the ESP32-S3 System on Chip. The main reason for using this microcontroller instead of other Arduino microcontrollers is the presence of Bluetooth and Wi-Fi. In this project, Bluetooth is used to wirelessly transmit the sensor data to a smartphone that runs software to present and visualize the stress level and the related measurements. Other criteria for choosing this microcontroller include:

* Compact size
* Low power consumption
* Dual-core processor for real-time processing of sensor readings
* I2C interface, used by the MAX30102 and MAX30205 sensors for communication

Its compact size and energy efficiency make it ideal to use in a portable device. A consolidated overview of all sensors used in this system and their integration with the Arduino Nano ESP32 is presented in table 1.

## MAX30102: heart rate and oxygen saturation sensor

The MAX30102 is an optical biosensor that measures the subject’s heart rate and peripheral blood oxygen saturation (SpO₂). It uses the I2C interface for communication with the microcontroller. Due to its compact design and low-power requirement, the MAX30102 sensor is optimal to use in wearable/mobile devices.

The sensor includes LEDs, photodetectors and low-noise electronics capable of ambient light rejection. Although it contains ambient light rejection, it is still advised to limit the ambient light interference to ensure measurement accuracy. The sensor uses both a red and an infrared (IR) LED to extract heart rate and SpO₂ via signal processing.

The sensor is initialized with a sampling rate of 100 Hz and is read in sequences of 100 samples to calculate the heart rate and SpO2 using an open source algorithm.

## Grove GSR Sensor: skin conductance sensor

The GSR sensor measures the skin conductance between two electrodes, which varies with sweat activity. Since skin conductance is linked to autonomic nervous system activity, it serves as a reliable indicator of stress.

It works by placing two electrodes on the skin (usually fingers) and applying a small amount of voltage. The resulting conductance is measured, with higher values indicating increased sweat gland activity. This can be the result of elevated stress levels.

The sensor outputs an analog voltage which is read using the pin A2 on the ESP32. An average over 40 samples is calculated to lessen the impact of fluctuations.

## Plux Piezo-Electric Respiration (PZT) Sensor: respiration rate

The Plux PZT Sensor is a sensor that is capable of gathering basic respiration data. It includes a chest-belt with a built-in piezoelectric sensing element (piezoelectric film) that gathers data by measuring respiratory motion. The sensor detects mechanical deformation of the sensor caused by changes in thoracic or abdominal volume when breathing.

The signal is read using the analog pin A0. A peak detection algorithm is used over a 60-second window to count the inhalations made within a minute. This results in a value for breaths per minute (BPM).

(<https://www.pluxbiosignals.com/products/respiration-pzt?srsltid=AfmBOoqX-ZqraYTy9DBPU243tGuNZ-K0sgG5AEa1SrWpJkrOwiXdz8Sm>)

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Function** | **Connection** | **Pin(s) used** |
| MAX30102 | Heart rate and SpO₂ via PPG | I²C | SDA/SCL (default Wire) |
| Grove - GSR Sensor | Galvanic skin response (skin conductance) | Analog | A2 |
| Plux PZT Sensor | Respiratory effort (chest movement) | Analog | A0 |

*Table 1: Summary of sensor functions, interfaces, and microcontroller pins used*

## Software Architecture

The firmware is written in C++ using the Arduino framework. The software handles sensor initialization, data acquisition, BLE communication, and command handling.

For BLE communication a custom BLE GATT service is implemented using the following UUIDs:

* **Service UUID**: 180C
* **Data Characteristic (UUID: 2A6E)**: Used to transmit sensor data (HR, SpO₂, GSR, and respiration).
* **Command Characteristic (UUID: 2A6F)**: Receives control commands from the mobile application.

The ESP32 is programmed to be able to support following commands:

* **START:** Begin continuous measurement from all sensors.
* **START HEART, START SPO2, START GSR, START BREATHING:** Begin measurement from a specific sensor.
* **STOP:** End all measurements and reset system flags.

Each sensor is handled by a dedicated function that enables sensor data acquisition. In each measurement loop, following steps are executed:

* **MAX30102**: Samples 100 values in a time frame of 500ms with a short delay in between reads, each from red and IR channels, processed by maxim\_heart\_rate\_and\_oxygen\_saturation().
* **GSR**: Samples the analog input 40 times over 200ms with a short delay between reads and calculates the average value.
* **PZT (Breathing)**: Over a 60-second window, the analog signal is sampled at 20 Hz. A basic threshold-based peak detection method is used to count breaths.

To avoid conflicts, the sensor readings are performed sequentially, particularly for analog inputs. A delay of 100 ms is introduced in the main loop to ensure system responsiveness and allow BLE event handling.

After each data acquisition, the data from each sensor is combined into a single string (e.g., "HR:75 SpO2:97 GSR:523 Breathing:15") which is sent to the BLE client via a notification.

## Application

This software offers a unified platform for the simultaneous monitoring of four key physiological parameters: heart rate, GSR, blood oxygen saturation (SpO₂), and respiration rate, in real-time and retrospectively. The program is designed with an emphasis on usability and interpretability, employing customized data visualizations for each parameter to be easily understood by users independent of technical background.

A key functionality that was introduced is a user account system, which allows organizations to deploy the monitoring tool without needing to purchase an individual device for each employee. The design allows multiple users to log in on a shared device, thus saving both capital expenditures and operating costs. Consequently, organizations can assign one hardware unit to be used by a group of users, who can use it at their convenience to assess their physiological measurements. The shared-device model not only reduces the cost per user but also enhances the overall accessibility of the system, thereby enhancing broader adoption in resource-scarce settings.

As part of the initial setup process, new users are prompted to enter their age, which is used for the purpose of estimating maximum heart rate. It is determined using standard physiological formulas that are commonly applied in health research (e.g., 208-0.7\*age) (<https://journals.viamedica.pl/folia_cardiologica/article/view/92507>) , and serves as the basis for the calculation of heart rate zones represented in the application's radial gauge visualization. These areas are color-coded to distinguish between resting, moderate, and increased levels of exertion, permitting intuitive evaluation of cardiovascular status.

Further, the configuration process includes a brief baseline measurement period during which the user's resting respiratory rate, mean heart rate, and mean GSR are recorded. These baselines are necessary to individualize the application's detection of stress level, as both resting respiration and GSR are inputs to the stress estimation algorithm, which allows the system to adapt to the physiological norms of each user.

Heart rate, respiration rate and GSR are shown using radial gauges, offering immediate, intuitive indication of current value versus set healthy ranges. A color gradient across normal, warning, and critical levels is implemented for the heart rate gauge, enabling users to assess their physiological state at a glance. SpO₂ levels are shown by a progress bar with dynamic color coding, enabling instant recognition of safe from problem levels

A central feature of the application is indicating stress, which integrates data from GSR and respiration rate to estimate the user’s current stress level. Research shows that GSR and respiration rate are valuable for stress detection, but does not establish specific threshold values for stress states. The focus of this research is the usability and not the algorithms or best values. For this reason, a “dummy” value for the critical GSR and respiratory rate is used. This approach enables the evaluation of interface usability independent of clinical validation. The resulting composite measure is communicated using a straightforward color-coded scheme—green, orange, or red—supplemented by a dialog box offering interpretive guidance. This approach ensures that feedback remains both transparent and actionable, supporting informed user response.

To enable longitudinal health tracking, the app features a history page for each parameter tracked. The screen is easily accessible by a button below each parameter. The user can toggle between graphical and tabular data presentation formats and select pre-established time-based filters ("Today," "Last 7 Days," "Last 30 Days") to modify the data range displayed. They are introduced as buttons positioned at the top of the interface, a design decision intended to preserve vertical screen space and interface legibility on handheld devices. The layout supports fast, low-effort navigation and minimizes cognitive load, thereby enhancing overall usability. The application follows the same data visualization strategy as Samsung Health (<https://www.samsung.com/nl/apps/samsung-health/?srsltid=AfmBOooJKtwJCQacqPGU1X9D35zN7cRpG8v84B7khVgoM3ZQlFHcImtg>) for displaying monthly and weekly trends, namely by utilizing bar graphs to represent the minimum and maximum value for each day. This is a method of providing a concise and easy-to-understand overview of daily variations without bombarding the user with excessive information. The graph emphasizes variability and outliers by plotting a day-to-day range instead of specific data points, thereby preserving visual clarity, which is necessary in case numerous days are plotted within small screen space. The approach enables users to compare easily between days and to spot trends. It is especially useful for mobile devices, where spatial constraints imply short but significant visual representations are required. Moreover, the utilization of bars over line graphs here avoids visual clutter and promotes interpretability, in accordance with proven best practices in mobile health data design. Taking a cue from the effective interface of Samsung Health, this approach balances information density with user comprehension, supporting both day-to-day check-ins as well as longer-term trend analysis.

To further enhance user comprehension and create trust in the system, the application includes a dedicated information panel for each health metric. This panel can be accessed via an info button on each parameter’s screen and provides clear, concise explanations of what each physiological metric represents (e.g., heart rate, GSR, SpO₂, respiration rate), why it is important for health, and how the measurement is obtained by the device. The information panel serves two purposes. First, it allows users to understand the significance of their readings. Such transparency explains health information, making the app more accessible and reducing confusion over unknown terms. Second, by explaining the sensor methods and the physiological basis for each measurement, the panel helps users understand the accuracy and limitations of the measurements. Together, these features help to reduce the "blackboxing" effect that remains a common issue among health monitoring apps today.

Through the use of adaptive graphical visualisations, individualised feedback systems, and interface design with the user in mind, this application seeks to make physiological health monitoring both feasible and accessible. The combination of easy-to-use interactive methods with visualisation techniques is designed to accommodate a broad variety of user needs, extending from informal self-monitoring to more structured health monitoring.

## Usability principles used

<https://www.nngroup.com/articles/ten-usability-heuristics/>

User-Centricity: The design is centered around the needs and abilities of your target users, employing clear icons, and intuitive navigation so users can interact with the app regardless of their technical background.

Consistency and Standards: Visual elements such as gauges, progress bars, and color codes are used consistently throughout the app. This adherence to common design patterns and conventions helps users quickly learn how to use different features and reduces confusion.

Visibility of System Status: Real-time feedback is provided through by displaying page titles and a loading screen while measuring.

Simplicity and Minimalism: The interface is intentionally uncluttered, showing only essential information and controls. This reduces cognitive load and helps users focus on key tasks, such as measuring or interpreting their health data.

Match Between System and Real World: The app uses real-world metaphors (e.g., gauges resembling analog dials) and everyday language, making it easier for users to understand the meaning of their data and actions.

Error Prevention and Recovery: The design includes clear feedback for actions like device pairing, and uses constraints and confirmation dialogs to minimize user errors and guide them in resolving issues if they occur.

Flexibility and Efficiency: Features like customizable thresholds and filters allow users to personalize their experience and quickly access relevant data, supporting both novice and experienced users.

Ease of Learning: The configuration process guides first-time users step-by-step, ensuring that even those unfamiliar with health monitoring technology can set up and use the app effectively

# User study

To evaluate the usability and user experience of the health monitoring toolkit, a structured user study was conducted. Participants were asked to complete a series of typical tasks using the app and then respond to a questionnaire covering various aspects of usability, clarity, and usefulness. Each question was rated on a 5-point Likert scale. The goal of the study was to assess how intuitive, informative, and engaging the app is for end-users, and to identify areas for improvement.

A total of 5 participants (2 students and 3 researchers) took part in the study. The participant group consisted of 4 males and a female between 22 and 24 years old. Most had limited prior experience with stress monitoring apps, allowing for a representative evaluation of ease of use from a general user perspective.

# Result

Participants rated each question on a scale from 1 to 5. They had a positive overall impression of the onboarding experience of the app. Device pairing was rated 3.6, reflecting an easy experience, while creating and selecting profiles was slightly less intuitive (3.4). Some participants were puzzled by the new user and existing user login screens being the same. Initiating a measurement was rated 3.8, reflecting that the majority of participants found it quite easy.

The clarity of the app was universally received, and the display of measurement results rated 4.6. Graphic elements like gauges and progress indicators hit 4.4, and the color-coded system scored an optimal 5.0 as proof of how effectively it assists users in interpreting their physiological values. The text content within the app was helpful (3.7), though one participant noted, however, that the quantity of the information could be viewed as excessive. But it did enhance the understanding of and working of the stress level indicator with a score of 4.4.

Graphical display of data was favored by participants over tables, with graphs receiving 4.4 for usability in monitoring trends. Most were unaware, however, that the "last 30 day" filter graph was touchable or scrollable and therefore gave incorrect min/max readings. Min/max rows in the table were rated lower (2.6), suggesting that this form of data presentation may be confusing or meaningless to users.

The history function itself was considered moderately (3.6) easy to access, while filtering by date range was perceived as intuitive (4.4).

Participants indicated gauge settings were easy to use (4.8) but were neutral in perceived usefulness (3.0), indicating a need to more clearly explain the benefits they may offer (e.g. indicating the acceptable range for the values for yourself).

Overall, the application was considered easy to use (3.6), with good functional integration (4.2) and minimal complexity (2.0). The application had minimal technical assistance dependency (1.4), and the majority of the participants believed that it could easily be accessed by novices (3.8). Nevertheless, the drive to utilize the application on a daily basis was inadequate (2.6), which indicates perceived long-term value deficiency. Confidence in the application was moderate (3.2), and prerequisite knowledge needed was minimal (1.8), indicating an easy learning process.

# Discussion

The user study provides insightful findings regarding the usability and user experience of the health monitoring app. The subjects scored the readability of result visualizations high (4.6), together with the utility of visualizations (4.4) and the use of color coding (5.0), which suggests that the app successfully conveys information related to stress.

Although device pairing (3.6) and profile setup (3.4) scores indicate the app is relatively intuitive overall, there is some room for improvement in the onboarding experience, possibly through additional instructional content or visual prompts.

The presentation of historical data was received with mixed reviews; the graphical presentation was preferred, but the minimum and maximum data rows in the table (2.6) were deemed unnecessary or confusing. Altering or eliminating this feature could enhance user satisfaction. Furthermore, more intuitive indicators for scrollable or touch-sensitive graphs are necessary.

The gauge settings were rated highly for both tunability and accessibility (4.8), yet were neutral in perceived usefulness (3.0), indicating a lack of sufficient in-app explanation or examples of its usefulness.

Although ease of use and low complexity were rated positively, future use intention of the app was extremely low (2.6). The disparity implies that although the application is technically sound and easy to use, its value proposition or engagement model may have to be enhanced (e.g. by features like goal tracking).

The low scores for "required technical assistance" (1.4) and "required prior knowledge" (1.8) indicate that the application is within the reach of the majority of users, a crucial prerequisite for mass utilization, particularly by amateur users.

Enhancing the positioning of the measurement buttons (e.g. not as options under another button) or renaming the 'Start Measurement' button would significantly increase usability.

Aside from the software, the entire health measurement toolkit, as a portable sensor and mobile app, is an affordable and accessible solution for non-invasive health monitoring. The physical product has potential application in work or school environments where there is limited access to inexpensive and interpretable tools for mental health screening. With additional refinement and streamlined onboarding processes, the toolkit would be poised to facilitate preventive mental health initiatives, biofeedback training, or ongoing wellness tracking in multiple environments.

# Conclusion (NEED TO DO)

This project demonstrates the feasibility and value of a low-cost, portable system for real-time monitoring of workplace well-being using physiological sensors and open-source hardware. By integrating heart rate, blood oxygen saturation, galvanic skin response, and respiration rate measurements into a single, user-friendly platform, the toolkit addresses limitations of commercial alternatives such as: high cost, lack of transparency, and limited accessibility. The accompanying mobile application further enhances usability by offering intuitive data visualizations, baseline calibration, and feedback, making physiological health monitoring accessible even to non-expert users.

The modular design and open architecture of both hardware and software provide a flexible foundation for future research, such as improved stress detection algorithms, additional sensor integration, or broader deployment within organizations. While the current system prioritizes usability and accessibility over validation, it establishes a robust platform for further research and development in occupational health technology. Ultimately, this work contributes to the growing field of workplace well-being by offering a practical, scalable solution for health monitoring, with the potential to inform data-driven interventions and promote healthier, more productive work environments.

# Acknowledgments

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References

1. TEMPLATE

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