A Smartwatch-Based Approach to Support and Analysis of Driver Stress and Anxiety

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Abstract: This study presents a smartwatch-based solution for monitoring drivers' stress and anxiety levels using heart rate data, standing out for not requiring synchronization with other devices. The system captures heart rate variations and GPS coordinates, offering real-time feedback to assist drivers while storing all data in a cloud database for subsequent expert analysis. Additionally, a reporting tool is provided to help specialists (e.g., psychologists) evaluate drivers' emotional states and offer appropriate support. A pilot study was conducted with eleven students from a driver training center during practical lessons to assess the proposed system. The results show that the application was positively received by all participants, with two expressing interest in using it beyond the study. These findings suggest that the proposed solution could enhance driver well-being and preparedness, particularly among new drivers.

1 INTRODUCTION

Traffic accidents are one of the world's leading causes of death (and the primary cause for individuals aged 5 to 29) resulting in approximately 1.19 million fatalities and between 20 and 50 million non-fatal injuries worldwide each year (WHO, 2023). In addition to the consequences for victims and their families, these incidents entail high economic costs, such as hospital expenses (Alhaek et al., 2024). In Brazil, in 2024, there were more than 13 thousand deaths and more than 1 million injuries in traffic accidents (Ministério dos Transportes, 2023).

Factors such as stress, anxiety and fear of driving contribute to the number of traffic accidents and cause other problems for drivers. For example, excessive stress generally leads to degraded driving performance, which increases the risk of road accidents (Zhao et al., 2024). Furthermore, driving anxiety correlates with poorer quality of life (Stephens et al., 2024), and finally, amazophobia (fear of driving), affects about 10% of the world's population (Craske et al., 2009). In fact, individuals with amaxophobia often avoid driving, which limits their mobility and quality of life, in addition to generating socioeconomic impacts (Vansteenwegen et al., 2014).

Different physiological parameters are explored in the literature to detect drivers' stress and anxiety, such as pupil dilation (Marquart et al., 2015), blood pressure (Li et al., 2021), galvanic skin response (Lee et al., 2023), among other physiological signals (Lin and Li, 2023), with emphasis on heart rate (Xu et al., 2024), which are widely studied (Haque et al., 2024).

Based on drivers' physiological signals, some studies focus on improving driver safety in real-time (Braun et al., 2019), exploring automotive user interfaces to assist drivers and help them during practical driving activities (Li et al., 2021). These methods commonly require different hardware resources that may demand experts or have a high cost, making some of these solutions inaccessible to most of the population due to their cost or technical complexity.

Many studies propose intelligent solutions to support drivers by detecting physiological signals related to stress and anxiety. However, few have focused

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on developing actual tools that summarize drivers' behavior and emotional states into reports for later expert analysis. Solutions that provide insights into drivers' behavior and stress/anxiety levels are essential for experts (such as psychologists) to offer appropriate support (Ortoncelli et al., 2020).

This work contributes to the literature by presenting a solution that monitors drivers' stress and anxiety levels using heart rate data, measured exclusively using a smartwatch without requiring synchronization with any other device, such as a smartphone. The proposed solution collects data from the driver's heart rate and the vehicle's GPS coordinates. Based on variations in heart rate, the application provides feedback to assist drivers in their driving activities. It stores all collected data in a cloud database, allowing experts to access the reports generated later and provide specialized support to drivers.

We decided to develop a solution that uses a smartwatch as the only device since there are models of watches that collect heart rate and run Android applications, making it possible to develop a simple solution that does not require synchronization with other devices and can be used quickly and easily. In addition, smartwatches have become popular with applications for leisure, health and research purposes (Barka and Politis, 2024; Pinge et al., 2024). In the transport sector, smartwatches facilitate cost-effective, unintrusive and dynamic monitoring of the driver's state and behavior while on the road.

In this context, the main contributions of this work are highlighted below:

- An application for smartwatches with the Android operating system monitors and supports drivers by collecting heart rate data and GPS coordinates during driving. It stores the data in a cloud database in real time and provides instant feedback to help drivers manage stress and anxiety;
- A script to produce reports that summarize the driver's heart rate and vehicle movement, so that specialists (such as psychologists) can analyze the driver's data and provide appropriate individualized care;
- The source code[1] of all implemented solutions is publicly available, allowing researchers and developers to access, review and enhance the system;
- The pilot case study was conducted with eleven students from a driving school in practical classes to obtain their National Driver's License, following procedures previously approved by the Ethics Committee for Research with Human Beings. We selected this public because we believe that providing adequate support to the stress and anxiety levels of driving students is essential so that they are better prepared to deal adequately with real traffic situations and can pass the practical driving test in less time.

Regarding the experiments carried out, in the participants' opinion, the use of the application was positive. Two of the eleven participants (the two with the highest stress level, according to the driving school instructor) showed interest in purchasing the application and the smartwatch to use in other driving activities, which is an indication that the proposed tool can positively contribute to helping drivers with stress and anxiety.

The remainder of this text is organized as follows. Section 2 presents details of the proposed tools. Section 3 details and analyzes the conducted case study. Finally, Section 4 presents the final considerations and future works.

2 PROPOSED TOOLS

The proposed approach uses an App on an Android smartwatch, which collects heart rate and GPS data from the driver during a driving activity, synchronously storing this data in a cloud database. The app also displays feedback to drivers according to their heart rate levels 2.1. We also developed a script that can present summarized reports of the collected data so that experts can analyze and assist the driver if necessary. Details about the application developed are in Subsection 2.2. The feedback provided to the driver according to heart rate levels is in Subsection 2.3. Subsection 2.4 describes the scripts developed to produce reports on the collected data. Subsection 2.5 outlines the data visualisation layer and the operational features of the dashboard.

2.1 Heart Rate Levels

Five stress and anxiety levels were considered based on the driver's heart rate. These levels were defined empirically and are used to provide feedback to drivers. Additionally we established these levels based on the number of beats per minute (BPM) of the driver.

The levels of stress and anxiety used are presented below:

- Z1: BPM lower than 116;
- Z2: BPM between 117 and 140;

[1] https://github.com/motaoliveiraufpr/CFCStress

- Z3: BPM between 141 and 158 ;
- Z4: BPM between 159 and 167; and
- Z5: BPM greater than Z4.

Regarding the heart rate levels considered in this study, it should be noted that there is no universally accepted standard for comparing heart rate. However, studies indicate that comparing the heart rate of experimental participants is a practical approach (Catai et al., 2020). The heart rate ranges used can be adjusted in future research by comparing the BPM collected in experiments.

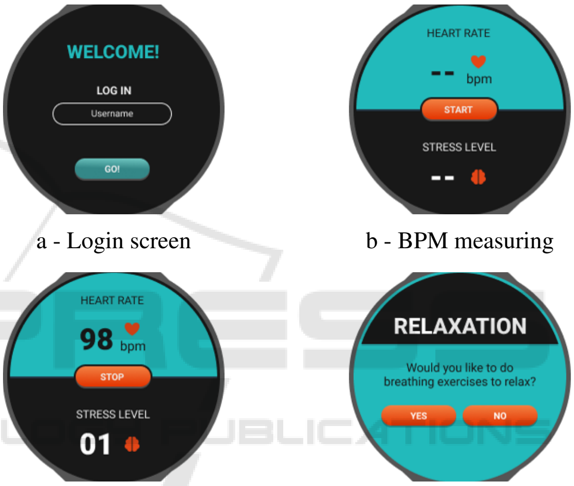
2.2 Developed App

The application was developed for the Android Operating System, with the Samsung Health Sensor API[2], to ensure compatibility with Wear OS. Furthermore, we used Kotlin[3] and Java[4] programming languages. In addition, for real-time data storage and synchronization, we chose the Firebase database.

Moreover, the MediaPlayer API of the Android multimedia framework was used to play the audio files which are in OGG format. To generate the audio files, we used the Vidnoz online tool[5], that provides different voice patterns – we chose the pattern entitled Elza, a friendly and articulate young female voice in Portuguese.

The following steps are followed for the app use:

1. The user needs to create an account in the app providing their name and login (Figure 1a).
2. The user must log in to the app (with their username and password) by clicking the **Start** button (Figure 1b).
3. If the user is logged into the app, it performs the following activities:
    - The app plays the audio: "**Welcome, my name is Juliana, I'm your virtual assistant**" (this audio is played in Portuguese). The presence of a name aims to humanize the interaction, making the experience more friendly and intimate;
    - In intervals of three seconds, the app monitors the heart rate and GPS coordinates, saving this data asynchronously in the cloud database;
    - The app displays the heart rate, as well as stress and anxiety levels (Z1 to Z5) on the smartwatch display (Figure 1c);
    - Every 6 minutes, the app plays an audio recording of the driver's heart rate zone (Z1 to Z5). The feedback texts/audios are in Subsection 2.3;
    - If the user is at levels Z4 or Z5, a pop-up is also displayed on the screen (Figure 1d); if the user stops the car and presses yes, the unlatching audio is played (described in Subsection 2.3);
    - New feedback is presented to the driver every six minutes, according to their stress level from Z1 to Z5.
4. When the driving activity ends, the user must press the stop button so that the app registers the end of the activity, stopping data collection and saving it in the database.



a - Login screen b - BPM measuring

c - Real-time heart rate d - Relaxation prompt

Figure 1: App Screens.

2.3 Feedback

The feedback explored is presented in this Subsection. In this paper, the texts are in English, but as the experiments were carried out with Brazilians, the app was implemented with the texts in Portuguese (the audios in Portuguese are in the project's GitHub repository).

For the lower stress and anxiety zones (Z1 and Z2), positive and motivational messages were used, encouraging the user to maintain their state, emphasizing pleasure and the experience at the moment. For the intermediate zone (Z3), the message alerts the user about the state change and offers a practical solution (deep breathing) to help control anxiety. For the higher zones (Z4 and Z5), the message provides instructions on breathing deeply to help the user relax physically and mentally. The use of counting during deep breathing helps to reinforce the practice and maintain focus on the process. It is worth noting that

[2]https://developer.samsung.com/health
[3]https://kotlinlang.org/
[4]https://www.oracle.com/br/java/
[5]https://pt.vidnoz.com/text-to-speech.html

breathing techniques in times of stress and anxiety are commonly mentioned in the literature (Leyro et al., 2021)

The texts used in the feedback audios are presented below:

- **Feedback for Z1 level:** "You are relaxed. Very good! Great job."
- **Feedback for Z2 level:** "You're cool, that's great! Enjoy the ride and enjoy the moment."
- **Feedback for Z3 level:** "You are entering a state of anxiety. How about relaxing with deep breathing? You can continue driving, but at this moment, take some deeper breaths; it will help you."
- **Feedback for Z4 level:** "You're in a state of heightened anxiety. How about taking a break? Stop the vehicle and let me know when you're in a safe place."
- **Feedback for Z5 level:** "You are in a state of very high anxiety. I advise you to stop the car as soon as possible to begin the relaxation. You must stop the vehicle and let me know when you are in a safe place to start the relaxation."

If the user is in the highest levels of stress/anxiety (Z4 or Z5), when he/she presses yes on the app (with the car stopped), he/she will receive the following feedback: "Now we are going to start the relaxation process, get into a comfortable position. You will inhale, fill your lungs and exhale, releasing all the air very deeply and slowly for five seconds. Let's go. One, two, three, four, five. Exhale one, two, three, four and five. Excellent job; you can repeat this relaxation for 2 minutes or 5 times. With this, we ventilate, strengthen the brain and have a more productive training session."

2.4 Report

To generate a mapped report of the heart rate data collected during each practical driving activity, we created a Python code using GeoPandas[6] and the Folium[7] libraries to visualize geospatial data interactively using Google Maps features.

Our tool connects to the cloud database, allowing us to obtain the data recorded by each driver during a driving activity. The entire route is drawn on the map based on the stored GPS coordinates, using markers with different colors for the moment the user is in each stress zone. The following markers colors were used: level Z_1 in green, level Z_2 in beige, level Z_3 in orange, level Z_4 in pink and level Z_5 in red.

[6]https://geopandas.org/

[7]https://python-visualization.github.io/folium/

Figure 2 shows an example of a report produced for a driver who passed through all the defined stress zones during a driving activity. In this report, the user can interact with the map by moving it and zooming in and out.

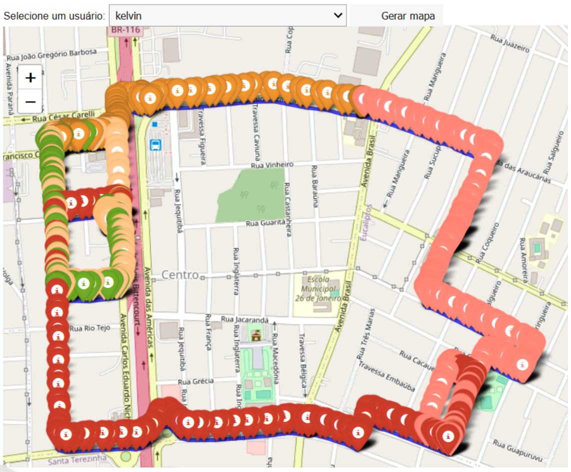


Figure 2: Reports produced.

It is important to note that these reports are important for specialists to analyze the driver's stress and anxiety levels in driving conditions, providing them with adequate support. The reports can be issued while the user is driving, and accessed by a professional in any other location with internet access. If necessary, this professional can interact with the driver immediately after the driver has finished driving or even during the driving activity (in extreme cases).

2.5 Data Processing and Visualization

In addition to processing heart rate and geolocation data, the system incorporates a more robust visualization module that generates interactive reports to illustrate the emotional intensity experienced during each driving session. These reports function as both pedagogical and psychological tools, supporting instructors and learners in identifying and reflecting on emotionally significant moments throughout the learning process.

The visualization tool uses geospatial plotting with color-coded stress indicators based on heart rate variability. Developed with responsive web technologies, it enables real-time and post-session access via desktop and mobile devices, promoting intuitive and user-centered interaction.

By combining wearable data with accessible interfaces, the system supports emotional self-regulation and learning in dynamic driving scenarios.

This two-layer (desktop + mobile) architecture enables the full cycle of monitoring → interpretation → intervention (Marceglia et al., 2015). Desktop dashboards address the longitudinal and multi-user supervision needs of the professionals, whereas the mobile app priorities real-time feedback and self-regulation—an allocation pattern recommended in multi-device human-computer interaction literature (Grubert et al., 2016). The approach leverages findings that wearable biofeedback lowers acute driving stress (Iqbal et al., 2022; Liu et al., 2023) and aligns with recent systematic reviews on stress-aware interaction design (Perez and Ruiz, 2024).

The desktop interface (Figure 3), shown below, was designed to allow specialists to monitor student performance through real-time reporting and post-session review of physiological and location-based metrics.

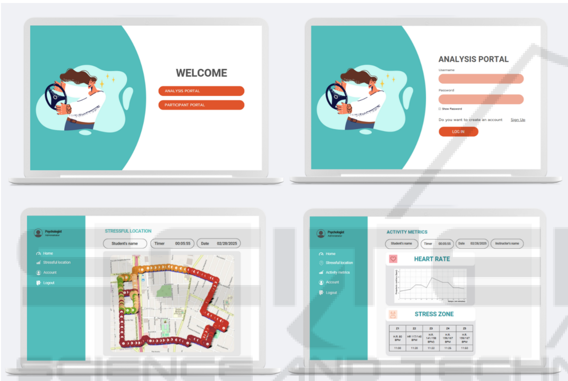


Figure 3: Desktop visualization.

The mobile version (Figure 4) further extends accessibility and interactivity with the feedback in a simplified and responsive environment, even during the driving session itself.

3 CASE STUDY

To validate the proposed tools, we conducted a case study using the hardware described in Subsection 3.1, which was applied in a pilot case study with eleven student drivers from a Driver Training Center (DTC), as described in Subsection 3.2. Supplementary material in Subsection 3.3 was provided in advance to familiarise participants with the underlying techniques and their intended applications. To evaluate the experience using the proposed solution, we applied questionnaires to the students (drivers), DTC employees and a psychologist specializing in drivers who fear driving. The experiment's results are in Subsection 3.4.

Figure 4: Mobile visualization.

We chose to run the experiments in partnership with a DTC, because the audience of participants in the experiment includes novice drivers (student drivers), who may have high levels of stress and anxiety due to their inexperience. Contributing to improving the training of these drivers can result in better drivers who pass the final exam to obtain their licenses more quickly. Apart from that, the Ethics Committee for Research with Humans previously approved all procedures performed.

3.1 Hardware Configuration

We used a Samsung Galaxy Watch 6 smartwatch, which was released in 2023, featuring the Wear OS 4 operating system with the One UI Watch 5 interface while offering an integrated experience with Android devices. This smartwatch has 2 GB of RAM, 16 GB of storage and a 5-nanometer Exynos W930 processor. Figure 5 shows a photo of this smartwatch used to run our application.

It is worth highlighting two possibilities for connecting to the internet with the smartwatch used: i) via Bluetooth/Wi-Fi, being able to obtain the internet routed from a nearby smartphone, and ii) its LTE version, which allows direct connection to the internet using an eSIM (Embedded SIM) without the need of a smartphone, which was the option used in the experiments.

Figure 5: Smartwatch running the proposed app.

3.2 Case Study Steps

To perform the experiments, we executed the following steps:

1. All students enrolled in the DTC who were taking practical driving lessons were invited to participate in the experiment.
2. We presented all methodological procedures to students interested in participating in the experiment, explaining that they could withdraw from participating at any time.
3. We consulted the DTC instructors to identify which students, among those who expressed interest in participating in the experiment, were most likely to exhibit signs of stress and anxiety. Based on their experiences in previous classes, the instructors identified eleven students.
4. Each selected student had to complete a free and informed consent form, as established by the ethics committee.
5. Participants were registered in the App.
6. Participants put the watch on their wrists, logged into the app and started the driving lessons.
7. Participants completed their class with the watch on their wrists, accompanied by a DTC instructor in the DTC vehicle. Each class lasted an average of 40 minutes of driving time.
8. At the end of the class, the students and the instructor answered a questionnaire with quantitative questions about their experience with the app.
9. A psychologist specializing in helping drivers with fear of driving accompanied the entire process, answering a questionnaire about the experiments and evaluating the reports produced with the data collected (Subsection 2.4).

3.3 Supplementary Material

In addition to the audio guidance provided during moments of high stress (zones Z4 and Z5), the software incorporates pre-training content based on mindfulness principles. Before the practical driving session begins, the student is given access to visual material with simple instructions on how to manage anxiety through techniques such as focused breathing, observing the environment, and accepting thoughts without judgment. This preparation aims to raise the student's awareness of the importance of emotional balance even before a stressful situation occurs.

This prior resource is intended to make the real-time feedback more effective. When the system prompts the student to stop the vehicle and begin the relaxation process, they are already familiar with the strategies to be used, which increases engagement and receptiveness to the exercise.

The preparatory content shown to the student before the driving session is based on simple and effective mindfulness strategies. Figure 6 presents the content used as an introductory mindfulness guide to the student before the start of the driving session. The guidance provided includes:

- **Present Moment:** Be aware of the current situation.
- **Observe Your Environment:** Notice sounds, smells, and physical sensations.
- **Focus on Breathing:** Focus on your breathing to calm yourself.
- **Acceptance Without Judgment:** Accept thoughts and emotions without criticism.

  Repeat a few times to reduce symptoms of anxiety and stress!

Figure 7 presents the diaphragmatic breathing content, which is presented to drivers and instructors, with the following step:

- Place one hand on your chest and the other on your abdomen.
- Inhale deeply for 3 seconds.
- Hold your breath for 3 seconds.
- Exhale through your mouth for 6 seconds.

  The user is encouraged to repeat the exercise a few times to reduce symptoms of anxiety and stress.

3.4 Results

The eleven student drivers who participated in the pilot study completed all the experiment activities and

Figure 6: Introductory mindfulness guide.

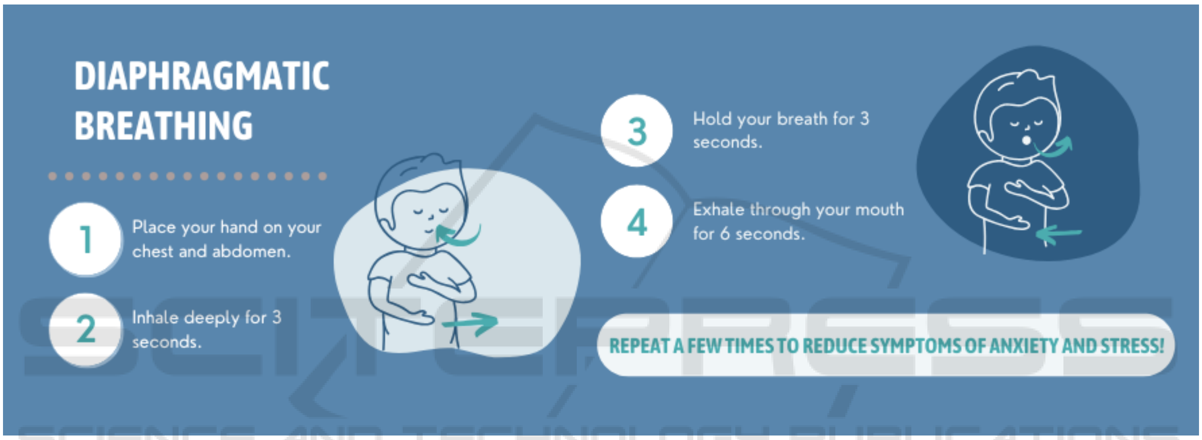


Figure 7: Diaphragmatic breathing guide.

reported no problems wearing the watch. A questionnaire was administered to all participants at the end of the driving activity. The questionnaire, alternatives and participant responses are presented below:

1. **Is the interface intuitive and easy to use?**
   - Yes: 11 answers (100%).
   - No: 0 answers (0%).
2. **Did the software help reduce your stress while driving?**
   - Yes, a lot: 7 answers (63.6%).
   - Yes, a little: 2 answers (18.2%).
   - It made no difference: 2 answers (18.2%).
   - No, it increased stress: 0 answer (0%).
3. **Was the sound alert helpful in reminding you to manage your stress?**
   - Yes, it was very helpful: 8 answers (72.7%).
   - Yes, but it could be adjusted: 1 answer (9.1%).
   - It made no difference: 2 answers (18.2%).
   - I found it irritating: 0 answer (0%).
4. **Was alerts frequency appropriate for you?**
   - Yes: 9 answers (81.8%).
   - It is necessary to reduce the frequency of alerts; they were very frequent: 1 answer (9.1%).
   - It is necessary to increase the frequency of alerts, there should be more: 1 answer (9.1%).
   - I didn't notice the warnings: 0 answer (0%).
5. **Did the software help you better understand your stress levels while driving?**
   - Yes, completely: 8 answers (72.7%).
   - Yes, partially: 0 answer (0%).
   - It made no difference: 3 answers (27.3%).
6. **Did you experience any discomfort with the software? If so, what was it?**
   - No, I didn't feel any discomfort: 9 answers (81.7%).
   - The sound of the alerts was unpleasant: 1 answer (9.1%).
   - The alerts were very frequent: 1 answer (9.1%).

7. **Would you use this software regularly in your driving lessons?**
   - Yes: 9 answers (81.7%).
   - No: 1 answer (9.1%).
   - Maybe: 1 answer (9.1%).

Survey results indicate that the app has an intuitive and easy-to-use interface, with 100% approval ratings. Most participants noted a significant reduction in stress while driving and found the audible alerts useful, although a small percentage suggested adjustments. Overall acceptance was high, with 81.7% saying they would use the software regularly, despite minor complaints about the sound and frequency of alerts.

In addition to the questionnaire, qualitative feedback was collected after each practical driving session monitored by the app developer, involving student drivers, DTC instructors, and the psychologist overseeing the experiment. According to the opinion of the six instructors who monitored the practical driving activities, with the use of the app, a slight increase in the students' confidence could be observed, presenting a positive impact on the learning experience of the students who did not experience any discomfort with the use of the app. The instructors also provided suggestions regarding the feedback feature, noting that its text could be improved and that it was triggered too frequently within a short period.

The specialist psychologist highlighted the impacts of the software on students' confidence, indicating that this is an extremely important factor since emotional security is an essential factor for effective learning to drive a vehicle. However, both the instructors and the psychologist point out the need to reevaluate the stress zones based on the data collected in the experiments. Besides that, they also suggested testing other patterns of sound alerts.

Regarding the students/drivers, it should be noted that none of the students entered zones Z4 and Z5 during the pilot case study. However, they still reported feeling less anxiety/stress when using the application, reporting that upon receiving feedback about their emotional state through the software, they felt more comfortable and demonstrated greater confidence in driving. It is also important to mention that 2 of the 11 drivers showed interest in purchasing the watch and the application to continue using it in other classes. New case studies are necessary with a broader audience, but the pilot study results highlight the importance of the proposed solution.

4 CONCLUSION

This study introduced a smartwatch-based solution for monitoring and analyzing driver stress and anxiety levels using heart rate data without requiring additional synchronized devices. The proposed system enables real-time data collection and feedback, assisting drivers in managing their emotional states while driving. The collected data is also stored in a cloud database, allowing experts, such as psychologists, to analyze reports and provide personalized support.

The pilot study was conducted with driving school students, demonstrating the system's feasibility and potential to improve driver well-being. The positive reception of the application among participants, including two individuals who expressed interest in using it beyond the study, suggests that the tool can contribute to safer and more confident driving experiences, particularly for novice drivers.

Enabling data analysis about the driver with reports is also one of the contributions of this work. In particular, the maps produced can be a valuable tool for specialized psychologists. Still, it is worth noting that new functionalities should be implemented in future work to improve the software that produces these reports, allowing the analysis of drivers' performance on different days/moments.

Despite these promising outcomes, some limitations must be addressed in future work. The current study involved a small sample size, and further research with a more extensive and diverse group of participants is necessary. The tool can be interactively adjusted based on the feedback received by experimenting with a larger group of drivers. It is worth noting that it is crucial to conduct experiments not only with student drivers but also with experienced drivers who report high levels of stress and anxiety.

In future work, in addition to adjusting the functionalities of the proposed tools, it is possible to explore other low-cost wearable devices that collect other physiological signals, such as galvanic skin response and respiration rate, to improve accuracy. Future developments could also explore machine learning techniques to enhance the detection and classification of emotional states in real-time, aiming to predict the moments in which drivers will enter high-stress and anxiety zones, and providing feedback in advance.

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REFERENCES

Alhaek, F., Liang, W., Rajeh, T. M., Javed, M. H., and Li, T. (2024). Learning spatial patterns and temporal dependencies for traffic accident severity prediction: A deep learning approach. *Knowledge-Based Systems*, 286:111406.

Barka, R. E. and Politis, I. (2024). Driving into the future: A scoping review of smartwatch use for real-time driver monitoring. *Transportation research interdisciplinary perspectives*, 25:101098.

Braun, M., Schubert, J., Pfleging, B., and Alt, F. (2019). Improving driver emotions with affective strategies. *Multimodal Technologies and Interaction*, 3(1):21.

Catai, A. M., Pastre, C. M., de Godoy, M. F., da Silva, E., de Medeiros Takahashi, A. C., and Vanderlei, L. C. M. (2020). Heart rate variability: are you using it properly? standardisation checklist of procedures. *Brazilian journal of physical therapy*, 24(2):91–102.

Craske, M. G., Kircanski, K., and Vervliet, B. (2009). *Fear of driving: Epidemiology, diagnosis, and treatment*. Oxford University Press.

Grubert, J., Kranz, M., and Quigley, A. (2016). Challenges in mobile multi-device ecosystems. *mUX—The Journal of Mobile User Experience*, 5(1):1–17.

Haque, Y., Zawad, R. S., Rony, C. S. A., Al Banna, H., Ghosh, T., Kaiser, M. S., and Mahmud, M. (2024). State-of-the-art of stress prediction from heart rate variability using artificial intelligence. *Cognitive Computation*, 16(2):455–481.

Iqbal, T., Simpkin, A. J., Roshan, D., Glynn, N., et al. (2022). Stress monitoring using wearable sensors: A pilot study and Stress-Predict dataset. *Sensors*, 22(21):8135.

Lee, M., Lee, S., Hwang, S., Lim, S., and Yang, J. H. (2023). Effect of emotion on galvanic skin response and vehicle control data during simulated driving. *Transportation research part F: traffic psychology and behaviour*, 93:90–105.

Leyro, T. M., Versella, M. V., Yang, M.-J., Brinkman, H. R., Hoyt, D. L., and Lehrer, P. (2021). Respiratory therapy for the treatment of anxiety: Meta-analytic review and regression. *Clinical psychology review*, 84:101980.

Li, W., Zhang, B., Wang, P., Sun, C., Zeng, G., Tang, Q., Guo, G., and Cao, D. (2021). Visual-attribute-based emotion regulation of angry driving behaviors. *IEEE Intelligent Transportation Systems Magazine*, 14(3):10–28.

Lin, W. and Li, C. (2023). Review of studies on emotion recognition and judgment based on physiological signals. *Applied Sciences*, 13(4):2573.

Liu, K., Jiao, Y., Du, C., et al. (2023). Driver stress detection using ultra-short-term HRV analysis under real-world driving conditions. *Entropy*, 25(2):194.

Marceglia, S., Fontelo, P., Rossi, E., and Ackerman, M. J. (2015). A standards-based architecture proposal for integrating patient mhealth apps to electronic health record systems. *Applied Clinical Informatics*, 6(3):488–505.

Marquart, G., Cabrall, C., and De Winter, J. (2015). Review of eye-related measures of drivers' mental workload. *Procedia Manufacturing*, 3:2854–2861.

Ministério dos Transportes (2023). Painel estatístico de acidentes de trânsito. https://www.gov.br/transportes/pt-br/assuntos/transito/arquivos-senatran/docs/renaest. Acessado em 11/11/2023.

Ortoncelli, A. R., Silva, L., Bellon, O. R. P., de Oliveira, T. M., and Daga, J. (2020). Summarizing driving behavior to support driver stress analysis. In *2020 15th IEEE International Conference on Automatic Face and Gesture Recognition (FG 2020)*, pages 587–591. IEEE.

Perez, M. d. l. C. and Ruiz, J. A. (2024). Detection and monitoring of stress using wearables: A systematic review. *Frontiers in Computer Science*, 6:1478851.

Pinge, A., Gad, V., Jaisighani, D., Ghosh, S., and Sen, S. (2024). Detection and monitoring of stress using wearables: a systematic review. *Frontiers in Computer Science*, 6:1478851.

Stephens, A., Collette, B., Hidalgo-Munoz, A., Fort, A., Evennou, M., and Jallais, C. (2024). Help-seeking for driving anxiety: who seeks help and how beneficial is this perceived to be? *Transportation research part F: traffic psychology and behaviour*, 105:182–195.

Vansteenwegen, A., Verhaeghe, S., Clercq, C., and Kircanski, K. (2014). The impact of driving anxiety on mobility, quality of life and socio-economic participation: A systematic review. *Clinical Psychology Review*, 34(8):673–688.

WHO (2023). Global status report on road safety 2023. http://www.abeetrans.com.br/abeetrans/?p=4213. Acessado em 20/11/2023.

Xu, G., Qin, R., Zheng, Z., and Shi, Y. (2024). An adaptive system for wearable devices to detect stress using physiological signals. *arXiv preprint arXiv:2407.15252*.

Zhao, Q., Yang, L., and Lyu, N. (2024). A driver stress detection model via data augmentation based on deep convolutional recurrent neural network. *Expert Systems with Applications*, 238:122056.