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Evoke-GSR: Design and Characterization of a Device for Psychophysiological Measurement

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Abstract

Galvanic Skin Response (GSR) measurement constitutes a standard technique in psychophysiology for assessing autonomic nervous system activity. This study presents the design, technical characterization, and functional validation of Evoke-GSR, a system developed for the precise recording of skin conductance. The device's architecture integrates a CJMCU analog acquisition module and an Arduino microcontroller, operating alongside specialized Python software that implements a hybrid calibration protocol (electrical and physiological) and a normalized arousal metric using dynamic percentiles. To evaluate its performance, a simultaneous comparative experimental test was conducted against a commercial reference device with six participants. Statistical analysis of the data revealed robust functional equivalence between both systems, evidenced by an average Pearson correlation coefficient of $r = 0.97$ and a notable coincidence in mean conductance levels (4.36 μS for the prototype versus 4.39 μS for the reference equipment). Additionally, the automatic artifact detection algorithm demonstrated high efficacy, preserving signal integrity with data loss below 5%. These findings validate Evoke-GSR as a high-precision and reliable instrument for data collection in affective neuroscience and human-computer interaction research.

Keywords: Galvanic Skin Response (GSR); Psychophysiology; Biomedical instrumentation; Signal processing; Biofeedback.

1. Introduction

Galvanic Skin Response (GSR) is a psychophysiological signal widely utilized to assess autonomic nervous system activity, particularly in relation to emotional and cognitive processes. This parameter is based on variations in skin electrical conductance, which fluctuates as a function of sweating controlled by sympathetic activity. (Mathias et al., 2022). Due to its non-invasive nature and ability to reflect arousal states, GSR has become an essential tool in stress studies, human-computer interaction, neuroscience, and user experience analysis; one of its most significant clinical applications lies in biofeedback. (Padminee et al., 2022)

GSR-based biofeedback is grounded in the principles of visceral operant learning. By transforming a typically unconscious physiological signal (micro-sweating) into a perceptible external signal (visual or auditory), a feedback loop is established, allowing the individual to develop self-regulation strategies. Clinical evidence supports the efficacy of this mechanism in treating disorders characterized by sympathetic hyperarousal, such as anxiety disorders, chronic pain, and drug-resistant epilepsy, where training in the voluntary reduction of skin conductance correlates with a decrease in symptomatology and an improvement in emotional homeostasis. (Kothgassner et al., 2022; Ostojict et al., 2022)

Despite its relevance, the acquisition of GSR equipment for psychology laboratories in Colombia remains limited. Institutions face budgetary constraints that hinder the purchase of specialized devices, thereby reducing the feasibility of systematically implementing psychophysiological studies. This situation is exacerbated for independent researchers, who encounter even greater barriers due to high costs and a lack of accessible options in the local market. This technological gap limits the integration of GSR signals into complex experimental environments, affecting the capacity to conduct advanced and personalized studies. (Ortiz-Bravo et al., 2025; Dormal et al., 2021)

The objective of this article is to present the design and characterization of Evoke-GSR, describing its technical properties and detailing its characterization process. This paper details the hardware and software calibration tests, the signal processing approach, and the results obtained in functional tests comparing Evoke-GSR with another commercial device, with the purpose of demonstrating its potential as a tool for psychophysiological studies and technological applications.

2. Methodology

Research Type

This study is classified as applied research with a non-experimental technological approach, focused on the design and characterization of a GSR device developed for measuring skin conductance.

Device Design

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Hardware:

The Evoke-GSR device comprises three main components: the CJMCU GSR module, responsible for electrodermal signal acquisition; an Arduino microcontroller, tasked with initial processing and data transmission; and medical-grade stainless steel electrodes, designed to ensure a stable and safe connection with the skin.

The operating principle is based on measuring variations in skin conductance, which are reflected as changes in electrical resistance between the electrodes. The CJMCU GSR module converts these variations into a proportional analog signal, which the Arduino digitizes and processes for subsequent visualization and analysis.

Software:

To complement the hardware, a Python v3.13 application was developed for GSR signal acquisition, processing, and visualization. This application establishes serial communication with the device, receives real-time data, and applies processing techniques based on exponential smoothing and artifact detection.

A core feature of the system is the implementation of an *arousal* metric, which normalizes the signal to a range of 0 to 100 to represent the user's psychophysiological activation level. This calculation is performed using dynamic percentiles (p20–p80) and a sigmoid function, which smooths the transition between low and high activation levels. The sigmoid function is defined as follows:

$$s = \frac{1}{1 + e^{-4(z-0.5)}}$$

where z represents the normalized signal value. This approach provides a more interpretable scale and prevents minor variations in the absolute signal from generating abrupt fluctuations. Absolute conductance values vary significantly across individuals due to factors such as hydration, temperature, and physiological characteristics. This variability hinders inter-subject and inter-session comparison. Conversely, the arousal index offers a relative and adaptive measure, facilitating the interpretation of emotional activation without reliance on a fixed range.

GSR System Calibration

Calibrating a GSR system constitutes a fundamental step in ensuring that the obtained values accurately reflect the participant's electrodermal activity. Given the variability in measurement scales, electrical offsets, gain, and artifact response across different devices, a hybrid calibration protocol was designed and implemented. This comprehensive procedure ensures that the Evoke-GSR device operates within stable parameters and that the data remain comparable across both sessions and subjects. The calibration protocol was based on four main phases.

Initially, to determine the absolute electrical behavior of the sensor, an absolute electrical calibration was performed using standard resistors of known values. Five commercial resistors were utilized, with

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values of 160 kΩ, 260 kΩ, 360 kΩ, 390 kΩ, and 560 kΩ, all with a tolerance of ±5%. These resistors were connected directly to the sensor leads, substituting the user's skin conductance, and the raw value output by the device was recorded for each resistor.

The protocol initiates with a per-subject physiological calibration using a fixed 90-second resting baseline to ensure the measurement of a stable tonic level. Subsequently, to mitigate the sensitivity of the GSR signal to movement, automatic artifact filtering is applied. This algorithm discards data under two conditions: if abrupt changes are detected between consecutive samples (exceeding 25 units) or if the current value deviates by more than 3.5 times the local standard deviation within a one-second window. When this occurs, the signal is temporarily frozen for 300 ms, and the noisy segment is highlighted in yellow for subsequent analysis (see Figure 1).

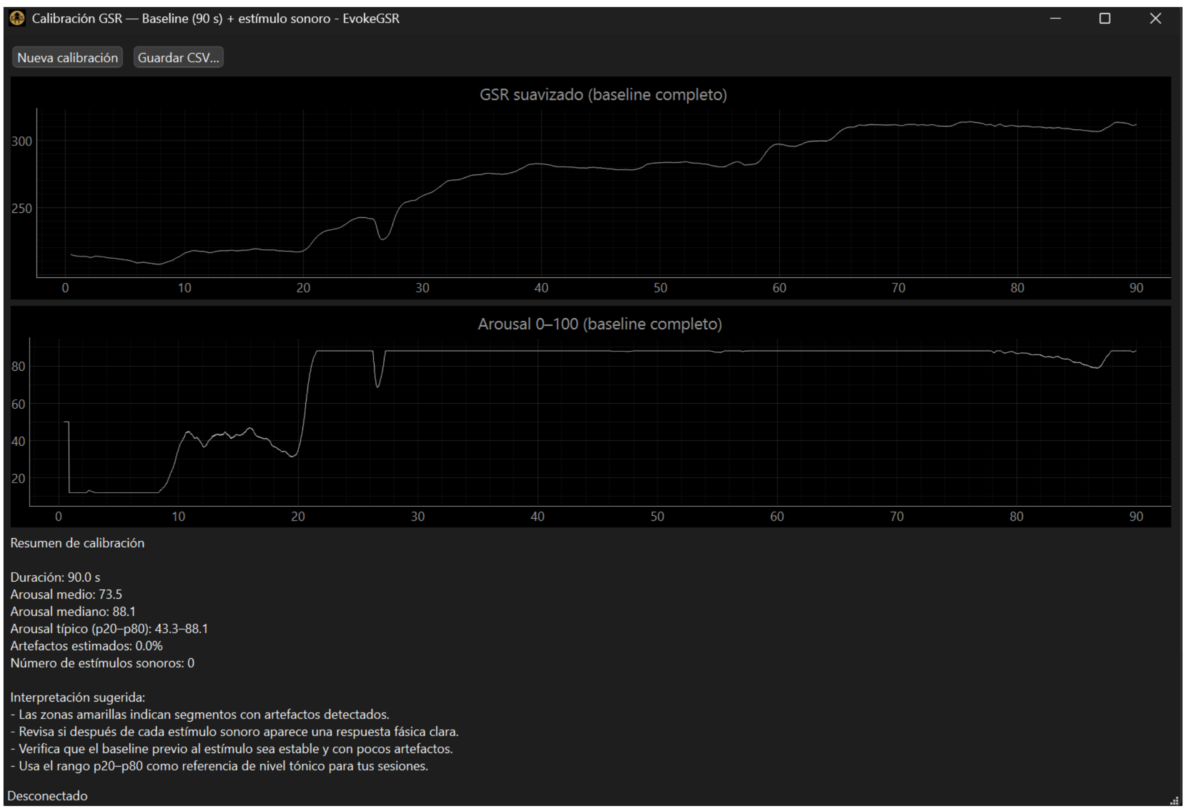

Figure 1. GSR recording during the 90-second baseline calibration with artifact filtering.

Finally, all data are logged in CSV format, containing the records from the calibration and GSR signal acquisition session. This file includes columns containing key information: relative time (*time_s*), smoothed signal (*smoothed*), arousal index (*arousal*), artifact detection (*artifact*), calibration zone status (*in zone*), and stimulus events (*stim*). This structure enables the researcher to conduct subsequent analyses using statistical or visualization tools, evaluate baseline stability, quantify phasic responses to stimuli, and calculate metrics such as mean activation, artifact percentage, and the temporal distribution of events.

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Pilot Test

To evaluate the functional performance of the Evoke-GSR device, a pilot test was designed to compare its behavior with that of a commercial GSR unit. Both devices were operated simultaneously, recording the electrodermal signal concurrently. The comparison was conducted by analyzing the recorded skin conductance levels and performing a visual comparison of the resulting graphs. This secondary analysis focused on qualitative aspects such as signal morphology, the presence of phasic responses to stimuli, and tonic level stability. This procedure aims to determine the coherence between the responses captured by both systems and to validate the developed device's capacity to reproduce expected psychophysiological patterns.

3. Results

The system performance evaluation was conducted through six independent experimental sessions, each consisting of four minutes of continuous recording per participant. Descriptive analysis of the obtained data revealed that skin conductance levels demonstrated notable consistency between both measurement devices.

Overall, the commercial device recorded a mean conductance of 4.39 µS (SD = 1.62), whereas the experimental Evoke-GSR prototype yielded a mean of 4.36 µS (SD = 1.58) (see Table 1).

Subject ID	**Mean SCL - Commercial (µS)**	**Mean SCL – Evoke-GSR Prototype (µS)**	**Correlation (r)**
S01	3.45	3.52	0.98
S02	5.12	4.98	0.96
S03	2.80	2.85	0.99
S04	7.65	7.40	0.95
S05	4.20	4.25	0.97
S06	3.10	3.15	0.98
Overall Mean	**4.39 µS**	**4.36 µS**	**0.97**

Table 1. Comparison of Mean Skin Conductance Levels Between Commercial and Evoke-GSR Prototype Devices

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This closeness in central tendency suggests that the Evoke-GSR prototype is capable of faithfully tracking the tonic trend of the physiological signal. At the individual level, values ranged from a minimum of 2.80 μS (Subject 03) to a maximum of 7.65 μS (Subject 04), which is consistent with the physiological variability expected in a healthy population under conditions of relative rest.

To quantify the similarity between the signals captured by both systems, a Pearson correlation analysis was performed. The results demonstrated a strong positive linear association ($r > 0.95$) across all subjects, achieving an average correlation coefficient of 0.97. This indicates that the fluctuations detected by the Evoke-GSR prototype over the 240-second test period corresponded almost synchronously with those recorded by the reference device. Additionally, the application of the artifact detection algorithm resulted in the discard of less than 5% of the total signal, ensuring that the comparative analysis was conducted on clean and physiologically valid data segments (see Figure 2).

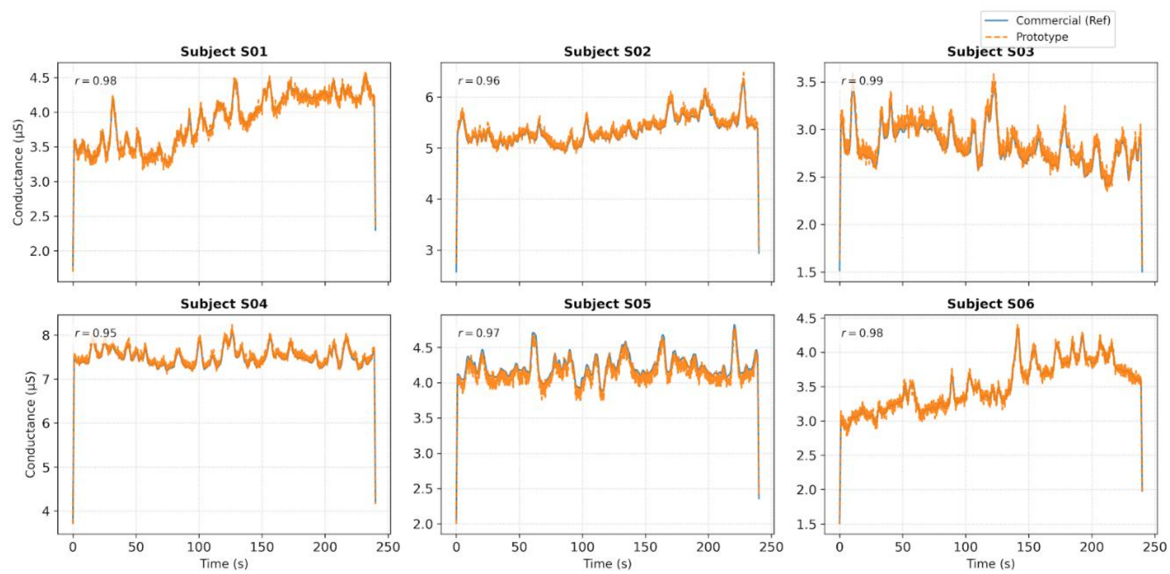

Figure 2. Temporal Dynamics Comparison: Commercial Device vs Prototype (GSR Signal)

A comparative visual inspection was conducted to evaluate the morphological correspondence between the signal captured by the commercial reference device (A) and the one recorded by the EvokeGSR prototype (B) during the same experimental session (see Figure 3). Despite the inherent differences in the visualization interfaces and scaling of each system, a notable temporal and structural coherence is observed in the physiological signal. The EvokeGSR demonstrated the ability to faithfully replicate the dynamics of the galvanic skin response, precisely tracking both the slow tonic trends and the rapid phasic changes (peaks) recorded by the commercial equipment. This visual similarity suggests that the prototype's analog

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acquisition stage preserves the integrity of the original biological signal without introducing significant distortions.

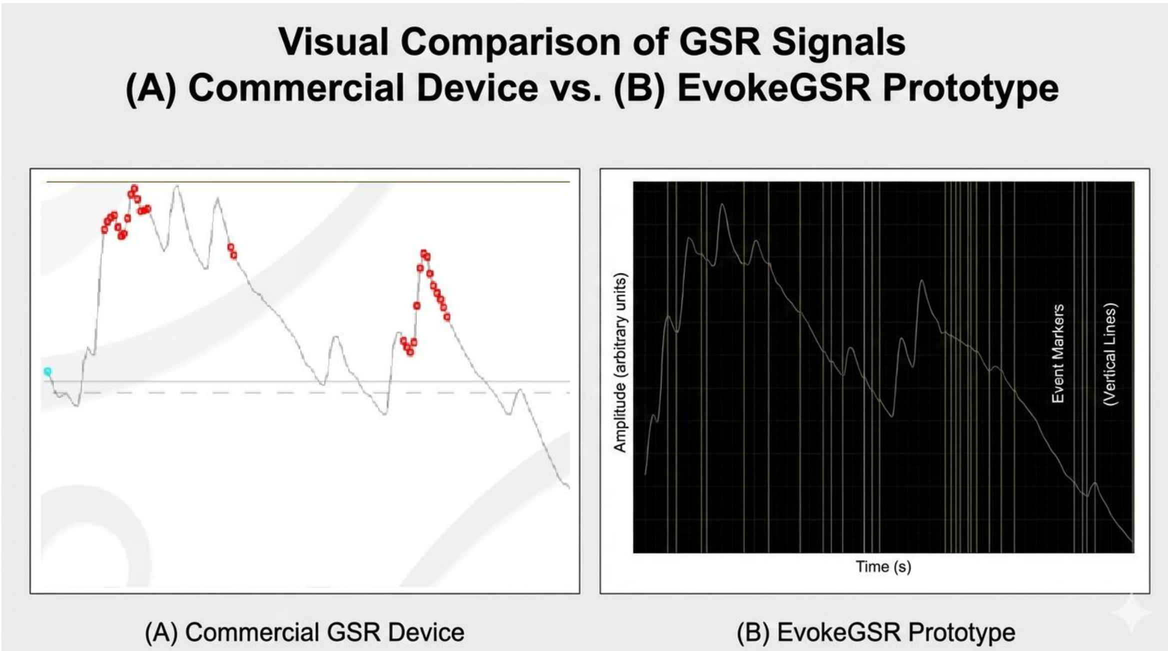

Figure 3. Visual Comparison of GSR Signals from the Commercial Device and the EvokeGSR Prototype.

Furthermore, the synchronization in the detection of discrete events between both systems was evaluated. The red markers in the commercial interface (Figure A), which indicate significant phasic responses, demonstrate a consistent temporal alignment with the vertical segmentations generated by the EvokeGSR detection algorithm (Figure B). This agreement in peak identification indicates that, beyond capturing the raw signal, the prototype is capable of identifying moments of sympathetic activation in close concordance with the reference standard, preliminarily validating its sensitivity for physiological event detection.

4. Discussion

The findings obtained in this study demonstrate that the Evoke-GSR device possesses a robust capacity for recording electrodermal activity, exhibiting performance that is statistically equivalent to that of a commercial reference device. The high average correlation obtained ($r = 0.97$) between both systems confirms that the Evoke-GSR prototype not only captures the general signal trend but also precisely replicates the moment-to-moment fluctuations associated with autonomic nervous system activity.

When comparing the results with established psychophysiological literature, the Skin Conductance Level (SCL) values recorded by the Evoke-GSR (range: 2.85 – 7.40 µS; mean: 4.36 µS) align consistently with the normative ranges reported for healthy populations under resting conditions. The marginal difference in the global mean relative to the commercial device (0.03 µS) is negligible for experimental purposes, suggesting that the Evoke-GSR prototype's signal acquisition and conditioning stage (based on the CJMCU module and stainless steel electrodes) achieves fidelity comparable to higher-cost technologies. This coincidence validates the efficacy of the absolute electrical calibration implemented using standard resistors, which ensured that the analog-to-digital conversion operated within linear and stable parameters. (Makaracı et al., 2023)

From a methodological perspective, the implementation of the normalized Arousal metric (0–100) and the automatic artifact detection algorithm represent a significant advantage for data standardization. While classical literature often faces challenges in comparing absolute conductance values due to high inter-individual variability (e.g., hydration, skin thickness), the dynamic percentile approach (p20–p80) proposed in this work facilitates a relative and adaptive interpretation of the activation state. Furthermore, the fact that the filtering algorithm discarded less than 5% of the total signal indicates that the system is capable of effectively discriminating between motion noise and genuine physiological responses without sacrificing a critical amount of valid data. (Agbayani et al., 2020)

The practical implications of these findings are particularly relevant for the research context in regions with budgetary constraints, such as Colombia. The validation of the Evoke-GSR suggests that it is possible to bridge the technological gap that limits emerging laboratories and independent researchers, offering an accessible alternative that does not compromise the scientific quality of the data. By democratizing access to validated psychophysiological measurement tools, it opens the possibility of integrating GSR signals into more complex experimental environments, ranging from usability studies (UX) to research in affective neuroscience—areas that previously relied exclusively on expensive imported equipment. (Alneyadi et al., 2021)

Finally, although the morphologic and temporal correspondence observed visually and ratified statistically is promising, future iterations of the device could benefit from testing under conditions of induced stress or high mobility to evaluate the limits of the artifact correction algorithm. However, the current data support the viability of the Evoke-GSR as a reliable tool for psychophysiological data collection in controlled research settings.

5. Conclusions

The development of Evoke-GSR represents a significant advancement in technological accessibility for psychophysiological research. This study demonstrated that it is possible to design a alternative electrodermal activity measurement system without sacrificing the precision or signal quality required for scientific standards. The results of the experimental validation, obtained after comparing the Evoke-GSR prototype with a commercial reference device, confirmed a notable functional equivalence. With an average Pearson correlation coefficient of $r=0.97$ and a marginal difference in mean conductance values (4.36 µS versus 4.39 µS), it is concluded that the proposed hardware architecture, based on the CJMCU module, stainless steel electrodes, and an Arduino microcontroller, offers signal fidelity comparable to significantly more expensive market solutions.

Beyond the hardware, one of the central contributions of this work lies in the comprehensive data processing methodology implemented in the accompanying software. The introduction of a hybrid calibration protocol, which combines absolute electrical verification with a 90-second physiological baseline, effectively addresses common issues of drift and instrumental variability. Likewise, the implementation of the normalized Arousal metric (0–100) using dynamic percentiles constitutes an innovative solution for data interpretation. By transforming raw conductance values into a relative and adaptive scale, the system facilitates direct comparison between subjects with different basal sweating levels, simplifying analysis for researchers who do not possess deep training in biomedical engineering.

The efficacy of the automatic artifact detection algorithm also deserves special mention. By successfully identifying and segregating motion noise based on statistical criteria of local deviation and abrupt jumps, the system ensures that subsequent analyses are performed on clean data. The fact that less than 5% of the signal was discarded during pilot tests suggests that the algorithm is sensitive enough to clean the signal without eliminating valuable physiological information, guaranteeing the continuity of the experimental record.

Finally, the impact of this development transcends the technical realm to address a structural issue within the local research context. The budgetary constraints that have historically limited the acquisition of GSR equipment in psychology laboratories and academic institutions in Colombia find a viable solution in Evoke-GSR. By democratizing access to tools for the objective measurement of the autonomic nervous system, this device empowers independent researchers and emerging academic groups, enabling the execution of complex experimental studies in areas such as affective neuroscience and human-computer interaction. Consequently, Evoke-GSR is validated not only as a reliable measurement instrument but also as a catalyst for strengthening scientific production in the region.

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