# Real-time Detection of Emotion Arousal by Electrodermal Activity Measurement

## An Android Application Design, Implementation and Test

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in Partial Fulfillment of the Requirements for the Degree of Master of Science

By
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# Abstract

Electrodermal activity (EDA), which is the property of the human body that causes continuous variation in the electrical characteristics of the skin, was widely used as a useful indicator of emotional arousal. In this project, we designed and implemented an Android application, which builds a connection to and obtain real-time streaming EDA data from Empatica E4 – a wristband measure physiological signals. The application can be used to measure the baseline and detect emotional arousals of the users. In order to validate the application, we use four movie clips as stimuli for emotion elicitation. Emotion arousals were detected when the participant is watching happiness movie and sadness movie; while no arousal was detected for neutral and excitement movie.


# 1. Background Introduction

## 1.1 Electrodermal Activity: a window on the arousal dimension of emotion

Electrodermal activity (EDA), also known as galvanic skin response (GSR) or skin conductance, is a measure of the conductance of a small electrical current applied to the skin, which indicates the level of sweating at the skin's surface. [1]

Since EDA is closely linked to autonomic emotional and cognitive processing, it is widely used as a sensitive (and arguably the most useful) psychophysiological index of changes in autonomic sympathetic arousal that are integrated with emotional and cognitive states and attention.[2] It is the only autonomic psychophysiological variable that is not contaminated by parasympathetic activity.[3,4] In particular, EDA can provide insights of emotions.[5] Since emotions regulate the autonomic nervous system, emotion arousals will lead to variations in the secretion of eccrine sweat on the skin's surface, resulting in the change of skin conductance. Therefore, variations in EDA level could be a pertinent body window on emotional processes. EDA can be used to examine both explicit emotional responses and implicit emotional responses that may occur without conscious awareness or are beyond cognitive intent.

EDA can be measured electrically in many different ways including skin potential, resistance, conductance, admittance, and impedance. In our project, EDA level is measured by the voltage drop between two electrodes placed on the skin surface a few centimeters apart using Empatica wristband, which will be discussed in the following part.

## 1.2 Empatica: a device to measure EDA and other physiological signals

In recent years, many wearable devices were designed and developed to measure physiological signals.[6] Empatica E4 is one of such device. It contains a photoplethysmography sensor, an EDA sensor and an infrared thermopile. The EDA level, as well as other physiological signals, including heart rate and skin temperature, can be measured by these sensors.

Users can download Empatica app for iOS and Android devices, which allows a real-time streaming of data from Empatica devices to a mobile phone. In addition, by using the API provided by Empatica connect website, users are able to build their own applications to obtain real-time physiological data, which can be interpreted to provide invaluable insights into the user's level of engagement and arousal.

### 1.3 UI/UX design: one of the applications

The real-time physiological characteristics measurement can be applied to the field of user interface and experience design. For example, people built a tool capable of automatically annotating and triangulating players' physiologically interpreted emotional reactions to in-game events.[7] Another example is to apply this technique in the area of professional securities traders' decision-making process.

The long-term goal of this project to integrate EDA measurement with other techniques, such as functional near infrared spectroscopy (fNIRS) to design new user interfaces.

## 2. An Android Application to Detect EDA Arousal

### 2.1 Design

Previous studies have focused primarily on time-averaged (over hours or tens of minutes) levels of EDA.[8] In this project, we were aiming to build an app, which can detect EDA arousal in real-time. That is, the app should be able to respond with the real-time change of EDA and when using this app, users do not need to wait until the end of the measurement section to see the results.

An EDA signal is constituted of two main components: a baseline level, which is varying slowly; and a phasic component, which is called skin conductance responses. The absolute value of EDA is affected by many subject-dependent and environmental factors, such as skin dryness and temperature. Even for the same participant, the baseline tonic EDA level may vary from day to day. So we need to find the baseline for each participant each time right before arousal detection process to avoid inconsistent results. To make it simple, our app only records the maximum and minimum values of the baseline. In the baseline measurements process, we measure the EDA values of the user while in rest condition and update the min and max. Note that, we discard the data of the first 10 seconds because the data are usually inaccurate and instable when the phone just connects to the Empatica wristband. In the arousal detection process, we use the minimum and maximum values defined in the previous step as a threshold to detect emotional arousal. So, whenever the EDA value goes above the maximum value then we assume that there is an arousal.

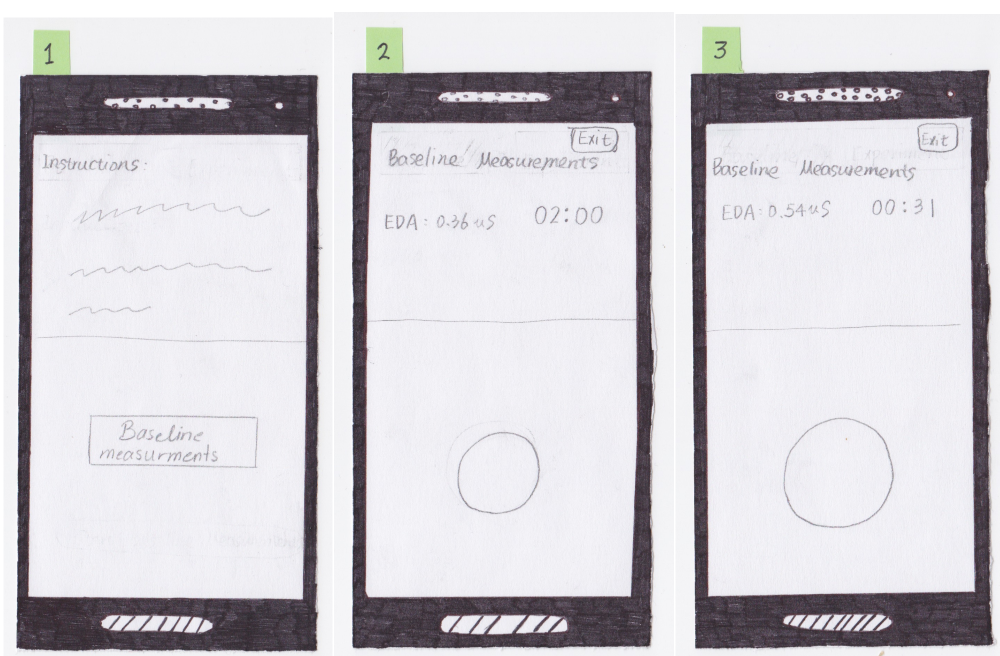
### 2.1.1 Paper Prototype

In order to enable our user interfaces to be rapidly designed, simulated and tested, we first built a paper prototype (shown in *Fig. 1*).

Our app includes three interfaces:

1. **Instruction page** (1 in *Fig. 1*): displays a brief introduction about the app.
    a. Baseline measurement button: start baseline measurement section.
2. **Baseline measurements interface** (2, 3, 4 in *Fig. 1*): finding the baseline (max and min) of the EDA values of the participant.
    a. EDA: EDA value, updated in real-time.
    b. Time: the time left for the baseline measurement section.
    c. Min/Max: minimum and maximum EDA values of the participant, shown after time is up.
    d. The demo circle: visualization of the EDA value. The size of the circle is changing in real-time based on the EDA value.
    e. The background: stay the same in the baseline measurement section.
    f. Exit button: disconnect the device and return to the instruction page.
    g. Arousal Detection button: start arousal detection section.

3. **Arousal detection interface** (5, 6 in *Fig. 1*): detecting EDA arousals
    a. EDA, the circle, exit button are the same as previous.
    b. The background: blue when no arousal happens; turns to purple when there is an arousal.



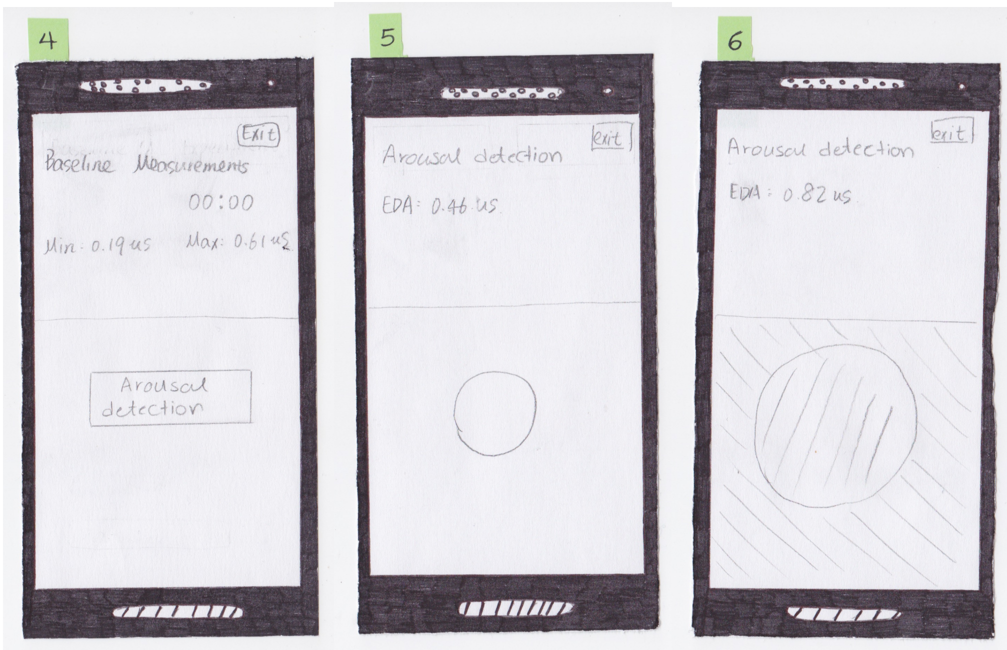
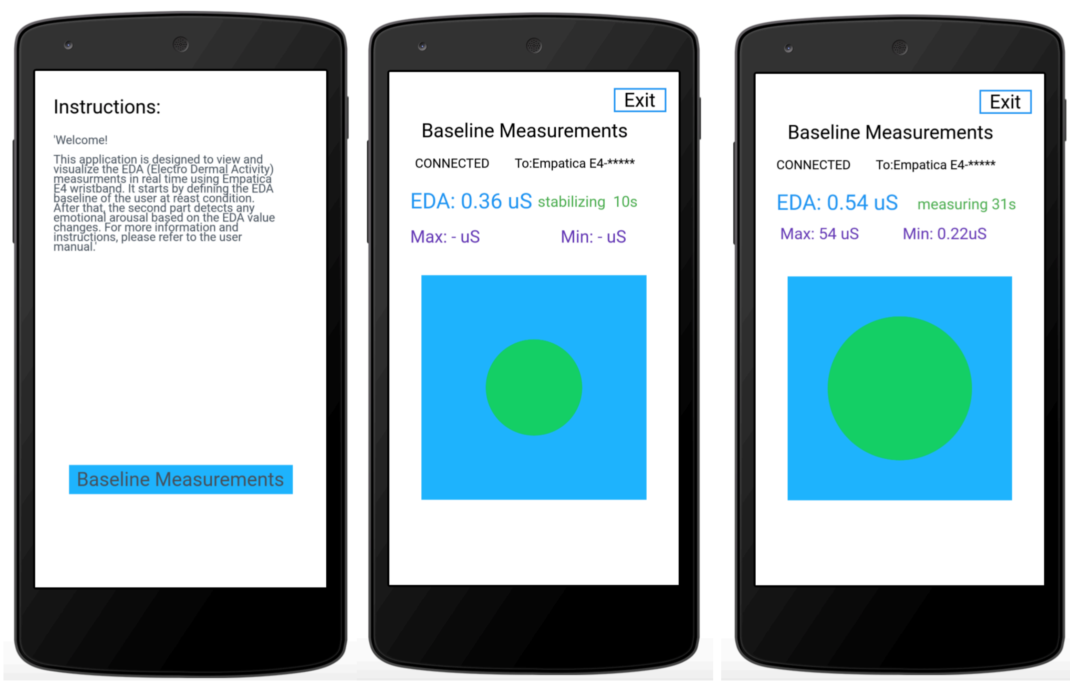



*Figure 1. The paper prototype*

### 2.1.2 Mid-fidelity Prototype

After discussed the design with our advisor and group mates, we modified some features in our design and built the mid-fidelity prototype (shown in *Fig. 2*)
The mid-fidelity prototype is built with Marvel app and the link is as follows: [https://marvelapp.com/4af421j](https://marvelapp.com/4af421j)



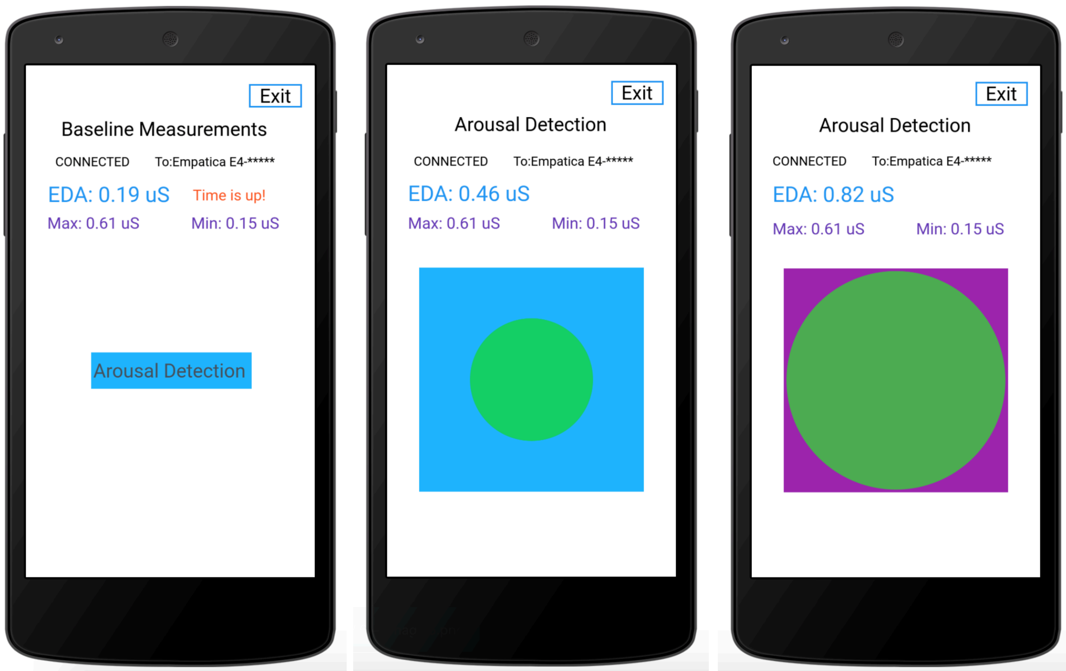



*Figure 2. The mid-fidelity prototype*

The modifications include:

- Add a text view to show the connection status. This will make it easier for the users to find the issues about connection.
- Show the stage of the measurements. For example, "stabilizing", "measuring", "time is up!" So the users will have a better understand about what is going on.
- Show the EDA value all the time, even when it is waiting.

## 2.2 Implementation

We built our Android application using Empatica API. In order to make it works, we first applied an API KEY to authenticate our application for accounting purposes and downloaded Android SDK.[9] Selected part of the code of the app and the user manual are in the appendix of this report. The source code of the app is available on Github at https://github.com/yanhuowang/EmpaticaDemo.

The implementation followed our design, except that we added a seek bar, which can manually change the size of the circle, for debug purpose.

## 2.3 Test

### 2.3.1 Overview

In order to validate our application, we designed to run simple tests on participants. We used a set of movies that were reported to reliably elicit four emotional states (happiness, sadness, neutral, excitement) to evoke the emotion change of the participant.[10] Movie clips have been widely used in emotion induction studies. The use of movie clips as stimuli for emotion elicitation offers many advantages over other methods, including ease of standardization and a high degree of ecological validity.[11] The movie set we chose has been validated by a previous research.[12] We picked four emotions from the set, including position emotion (e.g. happiness, excitement), negative emotion (e.g. sadness) and neutral emotion (e.g. neutral).

Each participant performed 4 experimental sections and the movies evoked different emotions were presented in counterbalanced orders between participants. EDA levels were recorded concomitantly. After each movie presentation, participants indicated their evaluation of the movie and reported the emotional experience.

### 2.3.2 Procedure

1. Ask the participant to sit comfortably. Let he/she wear the Empatica for 10 minutes, because the EDA value is very sensitive to the temperature. We need to make sure that the sensor is not too cold compared with skin temperature. During that time, we showed applicant the Instructions Document.

> **Instructions Document**
>
> We are going to use our application to measure your EDA level while watching different movie clips. You will be wearing Empatica E4 wristband. You will take 4 experiment sections in sequence. Each section include three parts:
>
> The first part, which lasts for 2 minutes, will be conducted while you are on rest.
>
> In the second part, you will be shown a movie clip for about 2-3 minutes.
>
> In the third part, please indicate your evaluation of the movie and report your emotional experience.

2. Let the participant relax and measure the baseline.
3. Randomly pick a movie. Show participant the movie without telling him/her the type of the emotion the movie evokes. When he/she is watching the movie, measure the EDA values and record the times and maximum value of the arousal.
4. Let the participant evaluate the movie and report the emotional experience.
5. Repeat step 2, step 3 and step 4 until all of the 4 movies are shown to the participant.

*Note that: during the whole experiment process, the participant cannot more his/hear hand or unfasten the wristband, because the EDA value is very sensitive to the pressure. The EDA value is usually higher when the pressure is high (when wear the wristband tighter).*

### 2.3.3 Results and Discussion

Due to the limited time, we only tested our app on one applicant. This test proved the validation of our application. At the same time, some limitations were revealed. In the future work, we may improve our application and perform more statistical test and experiment (will be discussed in part 4).

The information of the movie clips was shown in *Table 1* and results of the test was shown in *Table 2*.

| Title | Emotion | Year | Categories | Start Time | End Time | Total Time | Description |
|---|---|---|---|---|---|---|---|
| Love Actually | Happiness | 2003 | Positive | 1:00 | 2:00 | 1:00 | Starts with people hugging. A narration about love is superimposed over joyful reunion scenes from an airport. Ends after phrase "love actually is all around". |
| Up | Sadness | 2009 | Negative | 7:19 | 11:39 | 4:20 | Starts with a flash going off from a camera. Scene follows the life of married couple through many years up until the wife's death. Ends when her husband returns home alone from her funeral holding a balloon. |
| Manhattan | Neutral | 1979 | Neutral | 12:58 | 14:48 | 1:50 | A couple looks at art in a museum and discusses exhibits with another couple while walking around New York City. Ends as Woody Allen shrugs. |
| 300 | Excitemen t | 2006 | Positive | 44:16 | 46:31 | 2:15 | Scene depicts a battle between Persians and Spartans. Starts with an "earthquake" (actually caused by approach of Persian army). The armies approach one another as tension builds. Ends at the beginning of the fight. |

*Table 1. The information of the movie clips*

| Title | Emotion | Baseline Measurement | | Arousal Detection | Feedback |
|---|---|---|---|---|---|
| | | Min / µS | Max/ µS | | |
| Love Actually | Happiness | 0.167 | 0.186 | Two arousals were detected. The peak values were 0.227 µS and 0.215 µS. | It is joyful and sweet. |
| Up | Sadness | 0.201 | 0.414 | The arousals happened at the end of the movie. The peak value of the EDA was 0.437 µS. | The movie is really sad after the death of the lady. |
| Manhattan | Neutral | 0.354 | 0.546 | No detected arousal, the trend of the EDA is very flat. | This is a neutral movie. |
| 300 | Excitement | 0.597 | 0.660 | No detected arousal, but we did see some patterns (peaks). The peak value of the EDA was 0.630 µS. | This is a neutral movie. |

*Table 2. The results of the test*

We detected arousals when the participant was watching the happiness movie and sadness movie and no arousal happened during watching the neutral movie, indicates that our design and application works to some extent. In particular, the arousals happened at the end of the sadness movie, correspond with the movie that the sad part starts when the wife was dead, which was also at the end of the movie.

We did not detect any arousal in the excitement movie session, but the participant did not think this movie is an excitement movie as well. So in order to know whether the problem comes from our application or the movie, we need to do further investigation. But the EDA values did show some small peaks. Although these peak values did not exceed the maximum value of the baseline, the pattern of the excitement movie is different from that of the neutral movie.

# 3. Limitations & Future work

## 3.1 Only min and max are not enough

We only record the maximum and minimum values of the baseline. This simplification has several limitations. First, if an arousal happens during baseline measurement, a very high maximum will be obtained, which may cause no arousal can be detected during arousal detection section. Second, only two extreme values (min and max) are recorded, we lose all the other useful information.

Baseline is generally considered as the average tonic level of an individual during rest conditions and in the absence of any discrete environmental event or external stimulus. So in the future work, we should measure several max EDA values (for example, the five largest EDA values), and average them to get the maximum, instead of just one maximum value. Min should be obtained from the similar way.

### 3.2 Joint analysis of EDA and other physiological measurement

Previous research suggested that the emotion stimulus also cause the variation in heart rate and respiration rate. In the future work, we may perform joint analysis of these measurements to eliminate the effects of false peaks or missed beats.

### 3.3 Distinguish positive emotions and negative emotions

Our app can only detect arousals but we cannot distinguish the orientation of the emotion because both positive and negative emotions will lead to arousal.

Negative emotions have been reported to have a stronger influence on hear rate than positive or neutral emotions.[13] In the future work, we may use heart rate to distinguish negative emotions from positive emotions.

### 3.4 Deal with latency and other electrodermal temporal parameters

EDA activities are usually delayed 1–3 seconds, which makes it more complex to determine the relationship between EDA and sympathetic activity.

Besides the amplitude, which used in our application, EDA values are also characterized by three main temporal measures: their latency, their duration (rise time and recovery time), and their surface. In addition to the important analysis of amplitude, electrodermal temporal parameters had been interpreted tentatively as indicators of particular emotional or cognitive function. We may apply these parameters in or future studies.

### 3.5 Look for the relationship between the emotion arousals and self-reported emotional state.

From our test results, although the excitement movie did not evoke emotion arousals and the participant thought it was a neutral movie, the pattern of the EDA was different from that when the participant was watching the neutral movie. In previous research, EDA values have been used to investigate both the subjectively enlightened and hidden parts of emotional processing. In the future work, we may do some more research in looking for the relationship between the emotion arousals and self-reported emotional state. Furthermore, detect the emotions that the users do not recognize.

### 3.6 Machine learning

We may add some machine learning methods to our project. For example, use a set of movies that were validated to reliably elicit emotional states as input and EDA arousals as the output. Train the data to build a model to do classification.

### 3.7 Combine the real-time measurement with time-averaged measurement

The benefits of acquiring real-time physiological measurements must be balanced against the cost of measurement error, spurious signals, and other statistical artifacts.

In addition, our app only uses the current EDA value to do prediction. Instead, we could store all the previous data, and use all the data up to current time to make the prediction. This is also a real-time respond, but may lead to more accurate results. The demonstration is shown in Fig. 3.

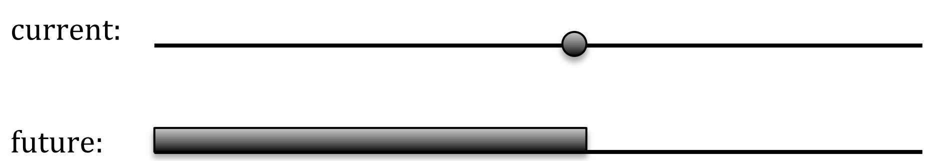



*Figure 3. Demonstration of using all previous data for real-time predication*

## Appendix

### Selected Part of Source Code of the Application

### User Manual of the Application

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