

2025年臺灣國際科學展覽會

優勝作品專輯

作品編號

130013

參展科別

行為與社會科學

作品名稱

Developing a Heart-Rate Monitoring App
to Help Families in Identifying Mood
Changes for Children Diagnosed With
Neurodivergence

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neurodivergence, Heart Rate Variability (HRV),
heart rate sensor app

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Developing a heart-rate monitoring app to help families in identifying mood changes for
children diagnosed with neurodivergence



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2024

ABSTRACT

This study dives into the benefits of a heart rate (HR) monitoring application to aid families in identifying mood changes in children diagnosed with neurodivergence. Children with neurodivergence often struggle with communicating their emotions, which often results in tantrums or emotional outbursts, and this study plans to address this by creating an app that detects users' HR to calculate heart rate variability (HRV) and detect when the user's heart rate variability (HRV) levels become higher than usual. Heart-rate variability is defined as a small variation of the interval between every heartbeat, it's calculated with the formula of $\frac{60}{BPM} \times 1000$. By looking at the developments of these small variations, it will be easier to notice then the interval for heartbeats are shorter, meaning the body is in need of more blood pumped quickly for support. The app is connected to a heart rate sensor that is worn by the user. The heart-rate sensor frequently uploads data to the app which the app processes and carefully observes while looking for any sudden, dramatic change. The sensor and app was tested and proved to meet the expected requirements of functionality. Four participants with neurodivergence were asked to equip the heart-rate sensor and results showed that different developments of heart-rate variability were able to be detected by the app, these participants varied in their type of neurodivergence as well as their age. As an example, the third participant showed the purpose of the app most visibly, having a resting heart-rate of 86 BPM (697.67 ms) turning into a high 107 BPM (561.68ms) after changing activities. When the user's sensor detects a sudden spike in heart-rate variability, the app notified the parent account about this change in emotion. This study has supported the relevance of using heart-rate variability to observe changes in mood.

Key terms: neurodivergence, Heart Rate Variability (HRV), heart rate sensor app

BACKGROUND

Children who are neurodivergent, such as those with autism, ADHD, or dyslexia, frequently struggle with communication in particular, which affects their capacity to interact with others, receive an education, and effectively express themselves. Individualized strategies and inclusive

communication are necessary to guarantee their best possible growth in nurturing settings. The value of assistive technology and tailored approaches in enhancing neurodivergent children's communication abilities in educational environments is highlighted by a study by Rose et al. (2023).

Children who are neurodivergent frequently exhibit increased sensitivity to emotional and

environmental changes, which can have a major effect on their capacity for communication. Their ability to express themselves, read social signs, or comprehend language can be affected by mood swings such as abrupt frustration, anxiety, or overstimulation. Children with autism, for example, could have trouble verbally expressing their feelings when they are in high emotional states, while children with ADHD might have trouble focusing during a conversation when they are feeling overwhelmed. Peer or teacher ignorance exacerbates these difficulties even further, potentially resulting in social exclusion or miscommunication. According to research by Smith et al. (2022).

When individuals undergo new or uncomfortable experiences, it releases a hormone called adrenaline. This hormone causes one's breathing and heart rate (HR) to rise, and eventually builds up to what's commonly known as "fight or flight" (American Heart Association). With this, there's a correlation between stressors and an individual's HR. Heart rate—more commonly known as pulse, is commonly recorded at 60 second intervals. The body automatically adjusts the HR based on the activity being conducted (Cleveland Clinic). Commonly, HR can be measured by placing three fingers on one's neck, but technological advancements have allowed for remote devices to detect one's heart rate.

When individuals are non-verbal or struggle with communication, one objective aspect to their emotions will always be HR. Regardless of age and gender, an individual will always have a heart rate that varies according to their situation, and the same

goes for children who have neurodivergence. We can use something called heart rate variability (HRV) which is a small variation of the interval between every heartbeat (Cleveland Clinic, "Heart Rate Variability (HRV): What It Is and How You Can Track It"). Previous studies have proven that most HRV indices were sensitive to uncomfortable states such as stress (Shi et al.).

Neurodivergent kids have the same developments of Heart Rate (HR) as healthy kids, meaning the amount of growth and decay their HR levels from certain emotions are the same as those of healthy kids. This is why it is essential that parents of neurodivergent kids know the patterns of their children's average HR to be able to determine when it is higher than usual to be able to intervene and help their child with facing their issues. This research helps parents observe their child's HR and use HRV to find any sudden changes of mood. HR sensor devices allow for an individual's heart rate to be recorded and sent to an application. The sensor uses an optical sensor to detect the light that's reflected from the blood (O'Donoghue). Through this research, we hope to help neurodivergent children through making an app that will observe their HR and analyze their HRV to help communicate their emotions to their parents through notifications when their mood may change dramatically.

RESEARCH QUESTION

Based on the background research, the following research question is formulated:

1. Can a heart rate sensor work with an app to detect a child's changes in heart rate in response to changes in mood?
2. How well can a heart rate sensor be able to tell users his/her ranges of emotions?

RESEARCH PURPOSES

In Indonesia, many children with disabilities have a hard time accessing resources to quality or even adequate support. Children with neurodivergence especially have a hard time with communicating their emotions and often end up expressing it in emotional explosions in the form of meltdowns or tantrums. Knowing that the biggest indicator of emotional changes is heart rate, the idea for an app surfaced.

HYPOTHESES

1. A heart rate app will be able to detect changes in mood
2. A heart rate app will be able to detect different ranges of emotion

METHODOLOGY

This app receives data from a sensor, so we developed a heart-rate sensor.

Main Components:

1. Microcontroller: Arduino Nano or ESP32 (ideal for wearable devices).

2. Heart Rate Sensor: Optical sensor like MAX30102 or Pulse Sensor.
3. Display Screen (optional): OLED 0.96-inch to display heart rate data.
4. Bluetooth Module (optional): HC-05 or BLE for data transmission to a smartphone.
5. Lithium Polymer (Li-Po) Battery: Small capacity, e.g., 3.7V 500mAh.
6. Battery Charging Module: TP4056 for recharging the battery.
7. Wires and Connectors: Jumper wires and JST connectors for the battery

Supporting Tools:

1. Breadboard: For prototyping the circuit before soldering.
2. USB Cable: To connect the microcontroller to a computer.
3. Soldering Iron and Solder Wire: For soldering components.
4. Bracelet Strap or Case: Material like silicone or plastic for housing the components.
5. Multimeter: To check electrical connections and voltage levels.

Steps to Create a Heart Rate Sensor Bracelet:

Heart Rate Sensor (MAX30102):

- VIN -> 3.3V on ESP32.
- GND -> GND on ESP32.
- SCL -> GPIO22 (I2C Clock).
- SDA -> GPIO21 (I2C Data).

- MAX3010x Sensor Library
- WiFi Library
- ThingSpeak Library

Figure 1: MAX30102 Heart Rate Sensor

OLED Display (Optional):

- VCC -> 3.3V on ESP32.
- GND -> GND on ESP32.
- SCL -> GPIO22 (shared with MAX30102).
- SDA -> GPIO21 (shared with MAX30102).



Figure 2: OLED Display

Battery (Li-Po):

- Connect the battery to the ESP32's power input (via a 3.7V Li-Po battery holder) or use a TP4056 module for charging.



Figure 3: Battery

Code for IoT (Using ThingSpeak)

This code sends HR data to the ThingSpeak platform. Ensure you create a ThingSpeak channel and obtain the API key.

Prerequisites:

- Install the following libraries in the Arduino IDE:

```
#include <WiFi.h>
#include <ThingSpeak.h>
#include "MAX30102.h"

// WiFi Credentials
const char* ssid = "Your_SSID"; // Replace with your Wi-Fi SSID
const char* password = "Your_Password"; // Replace with your Wi-Fi password

// ThingSpeak Channel Details
unsigned long channelID = YOUR_CHANNEL_ID; // Replace with your ThingSpeak channel ID
const char* apiKey = "YOUR_API_KEY"; // Replace with your ThingSpeak API key

WiFiClient client;
MAX30102 particleSensor;

void setup() {
  Serial.begin(115200);
```

Figure 4: Code for initial connection

```
// Connect to Wi-Fi
Serial.println("Connecting to Wi-Fi...");
WiFi.begin(ssid, password);
while (WiFi.status() != WL_CONNECTED) {
  delay(1000);
  Serial.println("Connecting...");
}
Serial.println("Connected to Wi-Fi");

// Initialize ThingSpeak
ThingSpeak.begin(client);

// Initialize MAX30102
MAX30102 particleSensor;
```

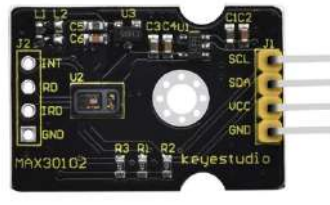


Figure 5: Code for

```
if (irValue > 50000) { // Basic check for valid data
  // Send data to ThingSpeak
  int httpResponse = ThingSpeak.writeField(channelID, 1, irValue, apiKey);
  if (httpResponse == 200) {
    Serial.println("Data sent successfully.");
  } else {
    Serial.print("Error sending data: ");
    Serial.println(httpResponse);
  }
} else {
  Serial.println("No valid heart rate detected.");
}
```

connection with sensor

Figure 6: Code for connection between sensor and app.

Steps to Set Up IoT on ThingSpeak

1. Create a ThingSpeak Account:
 - Go to [ThingSpeak](https://thingspeak.com/) and create a free account.
2. Create a New Channel:

- Add a new channel and name it (e.g., "Heart Rate Data").
 - Add a field (e.g., "Heart Rate IR Value").
3. Obtain Your Channel API Key:
 - Go to the API Keys tab and copy the Write API Key.
 - Replace the placeholder in the code with your API key.
 4. Upload Code to ESP32:
 - Use the Arduino IDE to upload the code to your ESP32.
 - Ensure the necessary libraries are installed.
 5. View Data on ThingSpeak:
 - Log in to your ThingSpeak account and open your channel.
 - The heart rate data will appear in the form of a graph under your channel's field.

Making the App

Flutter is a cross-platform app development framework by Google. This option is more customizable but requires programming knowledge.

Steps to Build the App

1. Set Up Flutter:
 - Install Flutter SDK from flutter.dev.
 - Set up your development environment (e.g., Android Studio or Visual Studio Code).
2. Create a New Flutter Project:
 - Run the command in your terminal:

```
flutter create heart_rate_monitor
cd heart_rate_monitor
```

Figure 7: Command for terminal

- Design the UI:

```
import 'package:flutter/material.dart';

void main() {
  runApp(MyApp());
}

class MyApp extends StatelessWidget {
  @override
  Widget build(BuildContext context) {
    return MaterialApp(
      home: Scaffold(
        appBar: AppBar(title: Text('IoT Heart Rate Monitor')),
        body: HeartRateMonitor(),
      ),
    );
  }
}
```

```
class HeartRateMonitor extends StatefulWidget {
  @override
  _HeartRateMonitorState createState() => _HeartRateMonitorState();
}

class _HeartRateMonitorState extends State<HeartRateMonitor> {
  String heartRate = "Loading...";

  Future<void> fetchHeartRate() async {
    final url = "https://api.thingspeak.com/channels/<YOUR_CHANNEL_ID>/fields/1/last";
    final response = await http.get(Uri.parse(url));

    if (response.statusCode == 200) {
      final data = jsonDecode(response.body);
      setState(() {
        heartRate = data['field1'] ?? "No Data";
      });
    } else {
      setState(() {
        heartRate = "Error fetching data";
      });
    }

    @override
    void initState() {
      super.initState();
      fetchHeartRate();
    }

    @override
    Widget build(BuildContext context) {
      return Center(
        child: Column(
          mainAxisAlignment: MainAxisAlignment.center,
          children: [
            Text('Heart Rate:', style: TextStyle(fontSize: 24)),
            SizedBox(height: 10),
            Text(heartRate, style: TextStyle(fontSize: 48, color: Colors.red)),
            SizedBox(height: 20),
            ElevatedButton(
              onPressed: fetchHeartRate,
              child: Text('Refresh ↓'),
            ),
          ],
        ),
      );
    }
  }
}
```

Figure 8 & 9: Code for the UI and codes for UI design

- Add HTTP and JSON Dependencies:

```
dependencies:
  flutter:
    sdk: flutter
  http: ^0.15.0
```

- Run the App:

Connect your phone or use an emulator. Run **flutter run** in your terminal to launch the app.

DATA AND RESULT

How it works - The app connects to the HR sensor and observes the HR bpm. Each minute, it tracks down the BPM of the user and puts it down to a graph. The application has three distinct features in the homescreen. The first is the heart rate monitor where users can observe the ongoing heart-rate of the bracelet's owner. Application users can sync the heart-rate of the bracelet users to determine their resting heart-rate. By determining the resting heart-rate, we can determine abnormal increases and decreases in the child's heart-rate. From then on, the app will feature the average hourly heart-rate of the bracelet user. The second feature of the app is labeled 'consult', which aims to provide consultation for app users in navigating difficult situations and how to handle them appropriately. The final feature is the emergency feature, which can contact emergency services and find the location of the bracelet user.

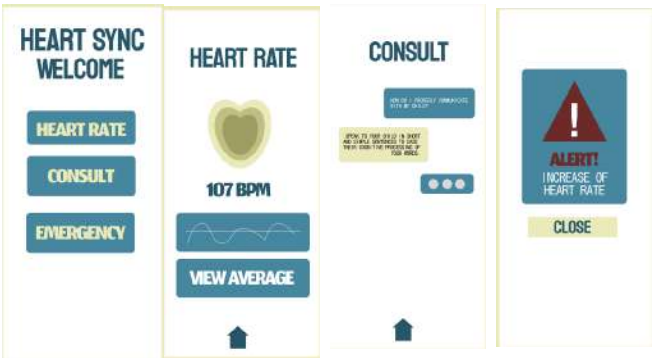
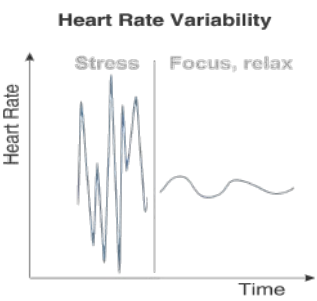


Figure 10-13: UI Design.



Figure 14-15: UI Design for Emergency services.

The application will feature the use of HRV as its main determinant for increases. When we count our heartbeats over the span of one minute, we simply count the total heartbeats and average it out over the whole minute. However, in between each heartbeat



there are small, but vital intervals of time. Averaging out the heart beats is a normal method of counting heart-rate for a short period of time, but to

Figure 16: Heart rate variability example

analyze varying emotions with heart rates, it will be more reliable to look at the change of the intervals in between the heart rates (Bailey). We can detect the emotions of individuals by observing their HRV developments. When an individual is in a relaxed state, their heart rate will follow a relatively stable pattern with not much fluctuation. However, when that individual begins to feel intense emotions, their heart rate will spike up and down, creating a graph

of wide variations of high and low heart rates. This method of observing HRV will easily identify any changes in an individual's overall changes in emotion.

Test our device, we equipped four neurodivergent children with the sensor for an estimated 15 minutes. Each of the children had their own varying reactions and HRV during the time of experimentation. We visited an educational center for neurodivergent children located in Kemang, Jakarta. This experiment was done with the consent of both the educational center and the parents of the children. To maintain the participant's anonymity, we will not be releasing their names and only make use of their ages and gender.

After the test run, several things were discovered: HR will increase during fearful, uncomfortable, and high-energy activity. As proven by spiking heart rates in test participants who went through activities such as swimming or felt uneasiness with wearing the HR sensor.

In test participant #1, the neurodivergent, 7-year-old male experienced a calm and controlled environment

Time (s)	Heart Rate (BPM)	HRV
15:30	100	600
15:31	96	625
15:32	93	645.1612903
15:33	92	652.173913
15:34	94	638.2978723
15:35	94	638.2978723
15:36	97	618.556701
15:37	97	618.556701
15:38	Washing hands	
15:39	101	594.0594059
15:40	101	594.0594059
15:41	101	594.0594059
15:42	101	594.0594059
15:43	101	594.0594059
15:44	101	594.0594059
15:45	101	594.0594059

Figure 17-18: Raw data table and R2 of test participant #1

SUMMARY OUTPUT									
Regression Statistics									
Multiple R	0.8833852								
R Square	0.78028341								
Adjusted R Square	0.76338214								
Standard Error	105.274451								
Observations	15								
ANOVA									
	df	SS	MS	F	Significance F				
Regression	1	911.6564925	911.6564925	461.671308	1.27E-01				
Residual	13	144.075231	11.0827101						
Total	14	655.732166							



Figure 19: Test participant #1 learning with a teacher.

with one adult. He was described to have trouble with following instructions and was occasionally disruptive. Thus, this test participant had a little change in HRV levels. In the beginning of the session, this test participant had a resting HR of 100 BPM (600 ms) while conversing with an adult. Throughout the session, there were some changes in this number, going to 92 BPM (652.17 ms), 97 BPM (618.56 ms), and then back up to 101 BPM (594.06 ms). Additionally, as shown by the R Square value of 0.78, his behavioral troubles likely resulted in the unstable HRV because a stable HRV would have an R square value above 0.9.

Test participant #2 was a neurodivergent 5-year-old female, who worked with an

Time (s)	Heart Rate (BPM)	HRV
15:51	102	588.2352941
15:52	102	588.2352941
15:53	102	588.2352941
15:54	102	588.2352941
15:55	102	588.2352941
15:56	102	588.2352941
15:57	102	588.2352941
15:58	102	588.2352941
15:59	102	588.2352941
16:00	103	582.5242718
16:02	96	625
16:05	96	625

SUMMARY OUTPUT									
Regression Statistics									
Multiple R	0.72406288								
R Square	0.52426702								
Adjusted R Square	0.4714079								
Standard Error	110.687006								
Observations	11								
ANOVA									
	df	SS	MS	F	Significance F				
Regression	1	121.513.692	121.513.692	991.617.566	0.01179093				
Residual	9	110.284.519	122.536.132						
Total	10	23.177.817							
Coefficients									
Intercept	-20.728.832	848.947.022	-24.474.743	0.03909933	-39.888.125	-15.695.352	-39.888.125	-15.695.352	0.86943667
	40.119.434	127.391.045	314.931.352	0.01179093	113.015.775	689.372.904	113.015.775	689.372.904	

Figure 20-21: Raw data table and R2 of test participant #2



Figure 22: Test participant #2 learning with a teacher.

adult teacher in a room with 2 other teachers behind her. Test participant #2 was described to need more assistance with fast speaking and this may be the cause for any higher-than-usual HRV levels. However, as a whole, this test participant had steady HRV numbers likely because of the controlled environment around her. When the R Square value of this test participant are counted, it is visible that this test participant is unstable, being 0.52.

On average, test participant #3, a neurodivergent 11-year-old male, had a resting HR of 86 BPM (697.67 ms) when eating. Then, once he approached the swimming pool, his heart rate spiked to 107 BPM (561.68ms) and continued to have that high HRV. A potential cause for this is a fear of the swimming activity which resulted in a change from a calm, happy mood to a more fearful and anxious state. As the R Square value is observed, it is also clear that this test participant has an unstable HRV with 0.35. Knowing that a stable HRV has an R

Square value above 0.9, it is clear how far this test participant is from having stable developments of HRV.

Time (s)	Heart Rate (BPM)	HRV
12:28	94	618.2678723
12:29	98	612.2448008
12:30	98	612.2448008
12:31	98	612.2448008
12:32	65	603.0768231
12:33	67	603.0768231
12:34	86	697.6744186
12:35	86	697.6744186
12:36	86	697.6744186
12:37	86	697.6744186
12:38	86	697.6744186
12:39	86	697.6744186
12:40	86	697.6744186
12:41	86	697.6744186
12:42	86	697.6744186
12:43	86	697.6744186
12:44	86	697.6744186
12:45	86	697.6744186
12:46	86	697.6744186
12:47	86	697.6744186
12:48	86	697.6744186
12:49	86	697.6744186
12:50	86	697.6744186
12:51	86	697.6744186
12:52	86	697.6744186
12:53	86	697.6744186
12:54	86	697.6744186
13:00	107	560.7476636
13:04	107	560.7476636
13:05	114	526.2157805
13:06	115	521.7391304
13:07	115	521.7391304
13:08	115	521.7391304
13:09	115	521.7391304
13:10	115	521.7391304
13:11	115	521.7391304
13:12	115	521.7391304
13:13	94	638.2678723
13:14	94	638.2678723
13:15	94	638.2678723
13:16	94	638.2678723
13:17	94	638.2678723
13:18	94	638.2678723
13:21	94	638.2678723

SUMMARY OUTPUT									
Regression Statistics									
Multiple R	0.59071135								
R Square	0.3489389								
Adjusted R Square	0.33033818								
Standard Error	788.661362								
Observations	37								
ANOVA									
	df	SS	MS	F	Significance F				
Regression	1	116.675253	116.675253	187.584775	0.00011859				
Residual	35	217.695377	621.986791						
Total	36	334.37063							
		Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept		322.446055	595.388744	541.572306	4.55E-02	201.575714	443.316396	201.575714	443.316396
0.52944444		-47.940645	110.689619	-43.311058	0.00011859	-70.412033	-25.469658	-70.412033	-25.469658

Figure 23-24: Raw data table and R2 of test participant #3



Figure 25: Test participant #3 in pool

Lastly, test participant #4, who was a 7-year-old male worked in a similar controlled environment as test participant #1 but, since the beginning, showed feelings of discomfort and uneasiness from wearing the HR sensor. This

resulted in a high HR and HRV of 126 BPM (476.19 ms). This test participant is ruled out to be an exception because the HRV values remained the same, having an R Square value of 1. This exception can be explained because the amount of time that the HR and HRV was taken for this test participant was very brief due to the uncomfortableness of the test participant. Additionally, the “stability” of this test participant’s HRV is also at a stable high, which simply means that the test participant has a high HRV that stayed high for the period of time it was recorded. If this experiment was conducted for a longer period of time, it might be possible for the R Square value to be lower with other potential values

Time (s)	Heart Rate (BPM)	HRV
13:50	126	476.1904762
13:51	126	476.1904762
13:52	126	476.1904762
13:53	126	476.1904762
13:54	126	476.1904762
13:55	126	476.1904762
13:56	126	476.1904762
13:57	126	476.1904762
13:58	126	476.1904762
13:59	126	476.1904762

SUMMARY OUTPUT									
Regression Statistics									
Multiple R	1								
R Square	1								
Adjusted R Square	1								
Standard Error	0								
Observations	9								
ANOVA									
	df	SS	MS	F	Significance F				
Regression	1	0	0	0	#NUM!				
Residual	7	0	0	0					
Total	8	0	0						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%	
Intercept	476.190476	0	65535	#NUM!	476.190476	476.190476	476.190476	476.190476	
	0.57638889	0	0	65535	0	0	0	0	

Figure 26-27: Raw data table and R2 of test participant #4.

To assess our hypotheses, we decided to develop a heart-rate monitoring feature to track down users’ HR throughout his/her day to look out for any sudden changes in HR. This will be determined through a user’s HRV based on their

resting heart-rate. Application users can make use of the average HRV to determine negative stimuli for their children to avoid in the future.

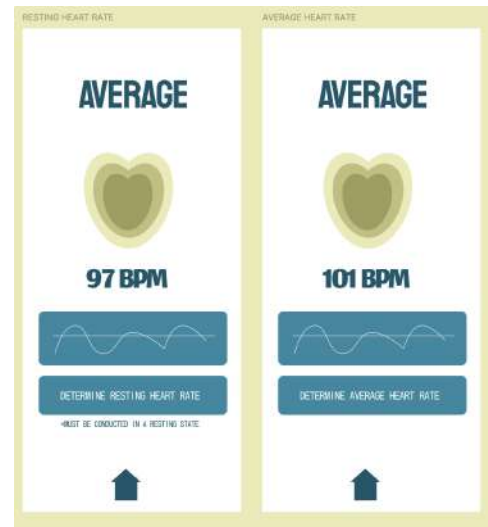


Figure 28: UI for Average heart-rate

With the app complete, we decided to test how well it does in detecting certain changes in emotions based on the HRV levels tracked by the app. By utilizing a biofeedback intervention application for parents to download, our app: HeartSync is able to connect with a smart-watch in which children can wear. When the user experiences a change in mood, HeartSync will be able to detect the level of stress and send an alert to the phone user. In doing so, the application user will be alerted of the situation they’re in. This will essentially alert parents to the distress that their child may be feeling, but unable to communicate appropriately. The app will have distinguishers of the levels of stress, which will also be alerted to the application user.



Figure 29: Interview with psychologist at the educational center.

It may be different for females than males, adults and children, healthy and neurodivergent people, so it is important to understand the cardiovascular mechanisms of varying individuals to make it specialized to their average scores.

We are not using the severity of stress but the change of heart rate in experiencing certain situations, as there are no general or common stress factors for everybody.

The results of the experiment proves the functionality of a heart-rate monitoring app for families with children diagnosed with neurodivergence in identifying changes in emotions. After we tested on four neurodivergent children, our application was able to quantify the HRV result of each individual child. This solidified the reliability of our device, as HRV and appropriate context serve as identifiers for the application users to determine which stimuli elicit positive or negative reactions for the children. Other than determining stimuli, families can make use of this device to monitor their children's activity. The device allows for the children's ongoing activity to be observed by

parents, which is especially helpful for children with more severe neurodivergence.

Our sensor still requires revisions that we found necessary for the future success of the product. The data itself still has tendencies to be delayed, which meant that not all data was in real-time.

CONCLUSION

The first hypothesis stating that a heart rate app will be able to detect changes in mood was H0 (accepted). From the data, it is seen that HeartSync was able to identify when there were sudden (or any) changes to an individual's HR/HRV. It became useful towards seeing how happy or fearful some test participants were when going through certain activities. Similarly, the second hypothesis of a heart rate app will be able to detect different ranges of emotion was H0 (supported). The app was able to use the history of tracked HRV values to compare with the active developments and detect when the user's HRV is higher than normal. In summary, HeartSync is successfully able to detect moments when a user's mood changes and can display the severity of how drastic his/her mood change is.

RECOMMENDATIONS

Strengths and Weaknesses

This study had several different strengths and weaknesses; with strong areas in meeting the original goals/hypotheses and weak areas with sample size and time constraints. The overall product was able to meet the planned purposes, allowing users to detect changes in mood through HRV development and also sending notifications to parent accounts when HRV numbers are concerning high.

While our product has its strengths, it does have some revisions that could be made in a different attempt. The original idea was to create an entirely new bracelet, but due to time constraints we had to work with a pre-existing *Samsung* watch. The use of the *Samsung* watch meant that the application would receive the data a minute or two after it would be processed. This delay served to be a weakness as the intention of the product is to ensure that family is updated on real-time data. The cause of this weakness is due to the sensor difference that the watch has compared to a custom sensor. A typical smartwatch only contains four green sensors to

detect the heart-rate of an individual, whereas a red sensor will typically be stronger in determining data.

Recommendations

Future studies should recruit a bigger sample size to provide for a wider dataset. Having a larger source of data will help in receiving more accurate results and determine if the product needs more revision. Future studies should also deepen their research by conducting experiments on neurotypical people to ensure the variability of the product for individuals who aren't neurodivergent, widening the scope of the product. Additionally, future studies are encouraged to use a more advanced sensor to receive data in real-time. The real-time data is essential in monitoring spikes in heart-rate for any possible negative reactions.

This study dives into the benefits of a heart rate (HR) monitoring application to aid families in identifying mood changes in children diagnosed with neurodivergence. Children with neurodivergence often struggle with communicating their emotions and this study plans to address this by creating an app that detects users' HR to calculate heart rate variability (HRV) and detect when the user's heart rate variability (HRV) levels become higher than usual. HRV is defined as a small variation of the interval between every heartbeat. By looking at the developments of these small variations, it will be easier to notice when the interval for heartbeats are shorter, meaning the body is in need of more blood pumped quickly for support. The app is connected to a HR sensor that is worn by the user. The HR sensor frequently uploads data to the app which the app processes and carefully observes while looking for any sudden, dramatic change. The sensor and app was tested and proved to meet the expected requirements of functionality. Four participants with neurodivergence were asked to equip the HR sensor and results showed that different developments of HRV were able to be detected by the app. As an example, participant 3 showed the purpose of the app most visibly, having a resting HR of 86 BPM (697.67 ms) turning into a high 107 BPM (561.68ms) after changing activities. When the user's sensor detects a sudden spike in HRV, the app notified the parent account about this change in emotion. This study has supported the relevance of using HRV to observe changes in mood.

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This study develops a custom device and app to monitor heart rate variability (HRV) and investigate its correlation with emotion. While HRV has been widely studied in the context of emotion detection in existing literature, the authors' creation of a proprietary device and app enhances the study's applicability. Additionally, the study includes a well-defined hypothesis, a robust scientific method, and a focus on clinical applications.

Below are several comments and suggestions for the authors to consider:

1. The study employs time-domain analysis for HRV. How does this method account for or distinguish parasympathetic and sympathetic nervous system activity?
2. What steps have been taken to validate the accuracy and reliability of the app?
3. How is the normal range of HRV for "normal emotion" defined, and what benchmarks or references are used to establish this range?
4. What are the inclusion criteria for participant selection? Additionally, what symptoms do participants exhibit, and are they categorized into the same group? Clarifying these points is essential.