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Design of a Biomedical Device to Reduce Anxiety Experienced by Patients Diagnosed with Parkinson's Disease

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ABSTRACT

Parkinson's disease (PD) is a neurodegenerative disease that occurs due to loss of nerve cells that produce dopamine in the brain, affecting approximately 4 million people worldwide. PD patients often feel an increase in anxiety levels daily. While there are medications/exercises to help relieve anxiety, there are limited methods to reduce anxiety without the help of a caretaker. As a result, MEDIC Foundation, a non-profit organization in British Columbia, Canada, is designing an automated system that consists of a wristband and an application which uses vibration therapy to help reduce anxiety of PD patients. Literature reviews were conducted to document the project's needs. Phase I of the project focused on developing a prototype for the application and phase II on developing the wristband. The team developed prototypes of a wristband that automatically applies vibration near the median nerve as the heart rate variability (HRV) deviates away from the normal threshold of the user, and an application that displays real-time heart rate variability signals as well as provides for relaxation. The development of the prototype is still in early progress. By creating this automated system, we aim to provide a solution to senior PD patients to relieve anxiety independently.

1. INTRODUCTION

1.1. Parkinson's Disease

Parkinson's disease is a neurodegenerative disorder which generally develops at the age of 60 with approximately 10% of patients being diagnosed earlier at the age of 50 [1]. It is generally caused by the degeneration of neurons in substantia nigra regions resulting in loss of dopamine neurotransmitters and thus reducing the facilitation of voluntary movement [2]. Currently, 1 in 500 Canadians have been living with PD since 2017 [3], and the prevalence is significantly higher for the population above 60 years old [2]. With this prevalence within our population, it is essential to continue to expand treatment options for patients with PD.

1.2. Symptoms and Comorbidities of Parkinson's Disease

Symptoms associated with PD include generalized slowing of movements, known as bradykinesia, resting tremor, and rigidity. Other associated symptoms are a loss of smell, sleep dysfunction, mood disorders and excess salivation [4].

Symptoms can vary per patient, however, a common psychiatric comorbidity in PD is anxiety. Anxiety associated with PD can be a result of both psychological and biological factors. Psychological factors refer to common fears and worries such as a fear of being unable to function independently, especially during the "off" state during which the medication is not working. Biological factors refer to brain pathways and chemicals affected by PD which are the same as those affected by anxiety and depression [4].

1.3. Current Treatment for Parkinson's Disease

Historically, movement disorders have been treated using medications which can biochemically restore weak neurotransmitters. One example is Levodopa for Parkinson's Disease which can increase the amount of dopamine produced in the brain and can improve motor performance. However, the major problem with long-term drug usage is the loss of efficacy where the drug no longer influences the system [5].

1.4. Current Treatment for Anxiety

Currently, conventional treatments for anxiety among PD patients include psychotherapy and medication. Non-conventional treatment includes but is not limited to relaxation techniques, acupuncture, vibration therapy and meditation [6]. The severity of PD symptoms can increase with age and as a result, at least one caregiver is required to care for a PD patient during advanced stages of the disease [7]. As a result, the need for a device that PD patients can use to treat anxiety independently arises, especially during the "off" state.

1.5. Deep Pressure Stimulation

Several devices are currently being used to treat anxiety using the principles of deep pressure stimulation (DPS). This is a form of therapy which involves the application of a firm, but gentle pressure to the body to help relieve symptoms of chronic stress or anxiety [8]. The mechanism of DPS is based on triggering the body's natural ability to relax by activating the parasympathetic nervous system.

1.6. Current Medical Devices to Help Relieve Symptoms of Anxiety

Devices that are being used to treat anxiety include but are not limited to inflatable jackets, weighted blankets, acupuncture mattresses and acupuncture bracelets. An inflatable jacket for example, is used by pumping air into a jacket which provides deep pressure stimulation to the upper body. However, for patients with heart problems, pressure application in the chest poses additional health risks.

Weighted blankets and acupuncture mattresses additionally require the patient to be in either in a supine or prone position and thus, there is a limitation in its use while the patient is performing active day-to-day activities such as walking.

Acupuncture bracelets apply pressure near wrist acupoints. However, a study by Du *et al.* investigated the effect of acupuncture on patients with psoriasis which concluded that acupuncture is not effective for anxiety for patients co-diagnosed with Psoriasis [9].

To address the limitations of the existing devices, the MEDIC Foundation investigated potentially novel therapies that can be applied through a wearable device.

1.7. Vibration Therapy and Impact on Median Nerve

In a study by Seco *et al.*, vibration therapy (VT) is considered to have an anti-stress effect. In the study, the authors investigated the effects of vibration therapy on hormone response and stress in severely disabled patients, evaluating their physical stress and state anxiety. The study concluded that the state of anxiety of the experiment group decreased significantly [10].

Furthermore, massages applied near median nerve have been associated with reduced anxiety. In a study by Field *et al.*, the authors investigated the effectiveness of massage therapy for relieving the symptoms of carpal tunnel syndrome which is caused by pressure on the median nerve. The experiment involved massaging 16 adults for 4 weeks, and the results showed lower level of anxiety [11].

The findings from the two studies suggest that vibration therapy applied close to the median nerve could be an effective method for alleviating anxiety.

1.8. Evaluating Anxiety

Anxiety can be evaluated using biomarkers such as Heart Rate Variability (HRV). HRV is where the amount of time between your heartbeats fluctuates. In a meta-analysis by Chalmers *et al.*, the authors identified that among 2086 patients with an anxiety disorder, those with a lower level of anxiety disorder showed lower HRV than the control group [12]. Based on this result, we may be able to use HRV as a measurement of Anxiety in a medical device.

1.9. Research Objective

We aim to develop a wearable device that can detect anxiety and effectively reduce its level while the user performs their day-to-day activities. Specifically, we are developing a wristband that automatically applies vibration near the median nerve as the heart rate variability (HRV) deviates away from the normal threshold of the user, and an application that displays real time HRV signals obtained from the wearable device as well as provides resources for relaxation. The purpose of this paper is to highlight the key procedure taken to prototype this medical device and explore the potential benefits of vibration therapy in relation to Parkinson's Disease.

2. MATERIALS AND METHODS

2.1. Literature Review

To first identify the correlation between vibration therapy and anxiety, a literature review was conducted which can be found in the appendix section. This literature review aimed to identify the needs and requirements for the application (app) and wristband prototypes. In the following sections, we will introduce the activities and the technologies that made possible the development of our research.

2.2. Need Statements

Post conducting a literature review, a correlation between the effectiveness of VT on anxiety was identified. The next stage was identifying the need statements of the 2 main components of the device; the app and wristband.

2.2.1. App Design

The objective of the app is to display the HRV signal in real time and provide resources to help reduce anxiety of the user. A research study by Tajudeen *et al.* was reviewed to identify the needs and requirements to develop a senior user-friendly and engaging application [13]. See **Table 1** for the needs used to develop the application in this project based on the guidelines provided by Tajudeen *et al.*

Table 1. **Guidelines for developing the application.**

Property	Need Statement
Backgrounds	There should be a high contrast between the text and background.
Icons and buttons	The buttons on the pages should be large.
Font and font size	Text should be easy to read for the user (font as San Serif and font size as 12 points).
Navigation	Use simple navigation on each page and offer the user a choice of navigation options.

2.2.2. Wristband Design

The objective of the wristband is to provide vibration therapy near the median nerve as the HRV signal deviates away from the normal threshold of the user. In a study by weeks-levy *et al.*, the authors explored features of wristbands desired by seniors to encourage their use by administering online questionnaires [14]. In the study, 105 seniors participated in the questionnaire above the age of 50. In the questionnaire, investigators provided a list of characteristics of the wristband, and the participants were required to rate the characteristics on a scale from one to five where one meant the characteristic was not important at all and five meant the characteristic was very important. The top five characteristics important to the seniors from the survey were selected and used as guidelines for our project, summarized in **Table 2**.

Table 2. **Guideline for developing the wristband.**

Property	Need Statement
Easy of donning the device	The wristband should be easy to wear.
Unobtrusiveness	Use of the wristband should not cause any obstruction for the user while performing day-day activities.
Soft materials	The wristband should be made of soft material.
Thin	The overall structure of the wristband should be thin.
Loose-fitting	A wristband should be loose-fitting for the user.

2.3. Resources to Reduce Anxiety

A growing body of research underscores the efficacy of various media forms in reducing anxiety levels. Music is one of the key resources to reduce anxiety. In a study conducted by Song *et al.*, the investigators concluded that listening to music helps reduce anxiety and pain of patients undergoing a biopsy [15]. Podcasts and meditations practices, particularly those focusing on mindfulness and mental health, provide valuable insights and techniques for anxiety management [16]. Reading informative articles, self-help books, or immersive fiction, offers both an educational and escapist route to calmness [17]. Additionally, video games designed with mindfulness in mind can serve as a unique tool for relaxation [18]. Each of these media types, from auditory to interactive, offers a distinct and accessible pathway to alleviate anxiety symptoms, making them a valuable complement to traditional stress-reduction techniques.

2.4. Vibration Design

When the HRV deviates from the user's normal threshold—a sign of potential anxiety—the wristband activates two mini vibration DC coin motors that are positioned to gently stimulate the median nerve. This subtle yet effective stimulation is intended to apply vibration therapy to reduce anxiety level as well as serve as a physiological cue, encouraging the wearer to engage in practices that restore HRV balance, such as focused breathing, meditation, or a moment of rest. The intensity and pattern of the vibration are carefully calibrated to be noticeable but not intrusive, ensuring a non-disruptive and user-friendly experience.

3. PROTOTYPE DEVELOPMENT

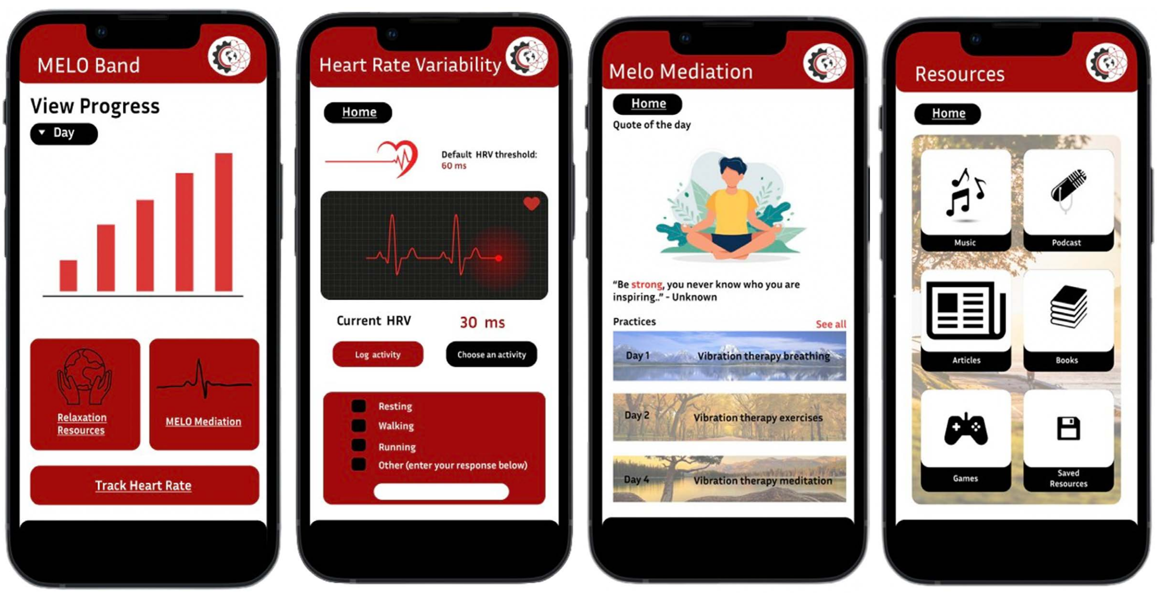
To develop the prototype, the project was divided into two phases. Keeping the guidelines for the application and wristband in mind, phase I focused on developing a prototype for the application using Figma design tool, and phase II focused on developing a CAD model prototype for the wristband using Solid Works.

4. RESULTS

4.1. Application Results

The mobile application is composed of four pages—home screen, a heart rate tracking page, a medication practice page, and a relaxation resources page. As per the guidelines stated in Table 1, dark texts on light background and light texts on dark background were used for a higher contrast between the text and background. The icons and buttons on the pages are designed to be large. The font used for the text is San serif and 14 points were used as the font size and a simple navigation system is integrated on the home page which provides the user a list of pages in the mobile application. A button to return to the home page is included in all remaining pages.

The Figma models for the various pages are presented in Figure 1.



(a) (b) (c) (d)

Figure 1. Mobile application prototype presenting the various pages of the application: (a) Home screen; (b) Heart rate variability and heart rate display screen; (c) Meditation practices display; (d) Relaxation resources page. A branding name of "MELO" band has been internally referred to within the research team which is a root word of "mellow", a verb to describe a relaxed and pleasant mood [19]. Please note that this brand "MELO" has not been licensed by our team and has been used informally to refer to medical devices.

The home screen is the first screen seen by the user and it provides an overall summary of the HRV signal for the day, week, month, and year using the drop-down list as seen in **Figure 1(a)** (Please see next section "HRV Estimation from HR" for details on how HRV can be calculated from HR). Additionally, it serves as a navigation point to the remaining pages in the application.

The heart rate variability display page displays the normal threshold of the user. The normal threshold is identified using the logs entered by the user while they are performing their day-to-day activities such as resting, walking, and exercise as seen in **Figure 1(b)**. It is recommended that the user continuously log their activity for one week prior to using the wristband to train the application to calculate the normal threshold of the user's HRV signal which will be used by the wristband to activate the vibration motor as the HRV deviate away from the normal threshold.

The meditation practice page, as seen in **Figure 1(c)**, recommended practices for mediation and the resources page, as seen in **Figure 1(d)**, provides sample music, podcasts, articles, books, and games which the user can utilize to reduce anxiety in addition to the vibration therapy provided by the wristband.

HRV Estimation from HR

To calculate the HRV from HR, we need to evaluate the HR data collected from the sensor in the time-domain. Time-domain analysis involves metrics such as Root Mean Square of Successive Differences (RMSSD) the number of pairs of successive NN intervals differing by more than 50 milliseconds (NN50) and pNN50 which is the proportion of NN50 divided by the total number of NN intervals. NN intervals, also known as the normal-to-normal intervals, are the periods between heartbeats.

RMSSD can be calculated by taking the square root of the average of the squared differences between successive NN intervals. See Equation (1) for the RMSSD calculation is:

$$\text{RMSSD} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N-1}\left(NN_{i+1} - NN_i\right)^2}, \tag{1}$$

pNN50 can be calculated using Equation (2):

$$\text{pNN50} = \left(\frac{\text{NN50}}{\text{Total NN intervals}}\right) \times 100\%, \tag{2}$$

RMSSD provides insight into short-term variations in heart rate whereas NN50 and pNN50 metrics provide insights into long-term variations in heart rate.

Visual representation of HRV can be obtained by plotting the NN intervals over time.

4.2. Wristband Results

The wristband prototype is divided into electrical and mechanical components. The electronic design of the electrical component is shown in Section 4.2.1 and the CAD model, and the drawing of the mechanical component is shown in 4.2.2.

4.2.1. Electrical Components

The electronic hardware design is presented in **Figure 2**, and the design is made up of the following:

- Breadboard
- Pulse sensor
- Vibration DC coin motor
- Arduino Uno
- BJT NPN transistor
- Four resistors (three 10% ± 1% W and one 1000% ± 1% W)

The algorithm to run Arduino Uno is included in **Appendix**.

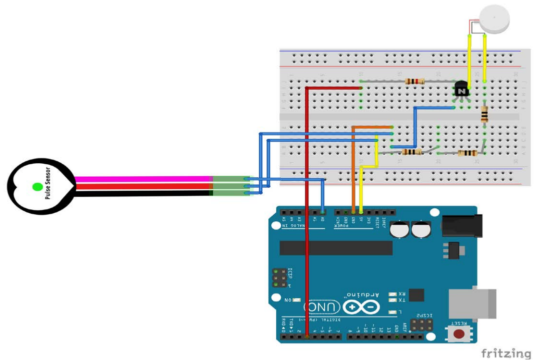


Figure 2. Electronic design of the wristband prototype.

4.2.2. Mechanical Component

The overall design of the wristband is presented in Figure 3. The material used for the wristband body is cotton linen, and the straps will be held together using Velcro. Cotton linen was chosen as the material as the guidelines presented in Table 2 require the wristband to be made up of soft material and thin whereas Velcro was chosen to hold the straps together as it will provide an easy method to wear the device, the user can choose the tightness and is advantageous for its unobstructed nature.

To better understand how the different electromechanical components fit inside the final design, the various assembly parts have been identified in Figure 3, and the CAD assembly of the device can be seen in Figure 4. The electronics design presented in Figure 2 will be placed inside the electric box.

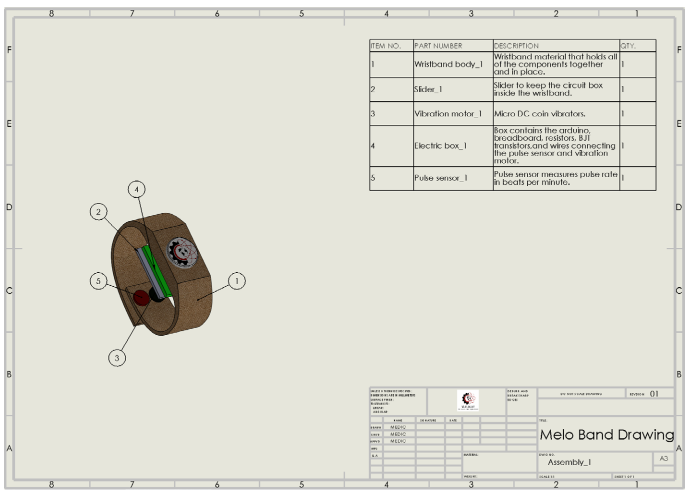


Figure 3. Bill of Materials for the Device.

Figure 4. CAD model of the wristband.

The pulse sensor and the vibrating coin motor connected to the breadboard and Arduino will be placed near the end of the wristband strap to measure the pulse and apply vibration near the median nerve. The slider will keep the electric box inside the wristband body.

4.3. Budget for the Device

To derive an initial cost estimate, we itemized the expenses associated with the procurement of components and materials necessary for assembling a single prototype. These components include an Arduino microcontroller, resistors, a breadboard, a pulse sensor, a vibration DC coin motor, a BJT NPN transistor, materials for 3D printing, and Velcro for fastening. The total cost for these components was calculated to be approximately 164.32 CAD.

However, recognizing the potential for cost reduction through bulk purchasing, we adjusted our cost estimation approach to reflect economies of scale. The procurement strategy for our components allows for the materials purchased in bulk to be sufficient for the production of four wearable devices. This adjustment provides a more accurate representation of the cost per unit in a small-scale production environment.

By dividing the total initial cost by the number of units that can be produced from the bulk materials (four devices), we arrive at a revised cost estimate of approximately 41.08 CAD per device. This figure offers a more realistic assessment of the production costs by leveraging the economies of scale associated with bulk purchasing.

It is important to note that this cost per unit is reflective of an initial small-scale production run and is expected to decrease with larger production volumes. This decrease is attributed to further economies of scale in materials procurement, as well as efficiencies in the manufacturing process that reduce labor and overhead costs per unit.

Additionally, to cover the data storage cost along with the mobile application fees, a monthly subscription fee of 10 CAD could be implemented.

5. DISCUSSION

PD is a progressive neurological and movement disorder which often induces anxiety. Various methods to mitigate anxiety have been explored for various purposes. However, no device currently provides senior-specific patients diagnosed with Parkinson's Disease a way to reduce symptoms of anxiety. The "melo" band, provides a two-fold approach; physiological monitoring and therapeutic intervention which both present a promising tool for improving the quality of life for individuals with PD.

5.1. Meeting the Needs of Parkinson's Patients

When discussing the results of our prototype, the primary consideration is whether the needs for our device have been met. In the following sections, we will discuss the considerations taken when developing the app and wristband for a PD patient.

5.1.1. App Design

The mobile app is an integral part of the device, and it has been designed for ease of use and accessibility. Each of the four main pages incorporated in the app is designed with the end-user, a PD patient, in mind.

1) Home screen: Large icons and clear text aim to guide a PD patient to various features of the app. Considerations were made for potential patients with tremors and/or vision problems in determining the size of the icons and text.

2) Heart rate variability tracking page: Real-time HRV data from the wristband is displayed here. This page has been made to consider key tracking points used by clinicians when examining a patient. A use-case for this page can be a caretaker who may need to refer to daily logs of patient heart rate variability. Future research applications may also be an opportunity with such real time tracking.

3) Meditation practice page: Clear resources are provided for PD-specific meditation strategies.

4) Relaxation resources page: A lifestyle approach to help guide early-onset PD patients with managing anxiety.

The four pages also incorporate all needs established in Section 2.2 to ensure that senior PD patients can independently control the app.

5.1.2. Wristband Design

The design of our wristband, specifically tailored for senior PD patients, prioritizes easy we arability, comfort and unobtrusiveness while ensuring functionality. The following design strategies have been chosen to ensure that the design meets these critical requirements.

1) Material selection and structure: Being lightweight, breathable, and gentle on the skin, we chose cotton linen specifically to reduce the risk of irritation or discomfort during prolonged wear. Additionally, the slim profile of the wristband can ensure that it does not feel bulky or cumbersome to maintain regular use.

2) Fastening mechanism: The use of Velcro for the wristbands strap is a deliberate choice, aligning with the requirements for ease of use and adjustability. For patients with reduced dexterity or tremors, Velcro allows for an effortless application and removal. The fastening mechanism additionally enables the user to adjust the tightness of the wristband, ensuring a snug, yet comfortable fit that does not impede blood circulation.

3) Unobstructedness and user experience: The wristband has been designed to be subtle and stylish, blending in with everyday wear. This is especially important for seniors who may be self-conscious about wearing a medical device. The thin design ensures that the wristband does not interfere with daily activities, making it more likely to be worn consistently.

5.2. Practical Implication

The development of a wearable device, specifically a wristband, capable of detecting anxiety and actively reducing it, has significant practical implications, particularly in the context of healthcare and personal wellbeing.

For those who have contraindications for anxiety medications or prefer non-medication approaches, this wristband provides a non-pharmacological and non-invasive method for anxiety management. Furthermore, the continuous monitoring of HRV allows for the immediate detection of anxiety symptoms, facilitating timely intervention. This real-time response can potentially prevent the escalation of anxiety episodes.

The design of the wristband focuses on user comfort and ease of use, making it suitable for a wide range of users, including the elderly, or those not technologically savvy. The accompanying app enhances the user experience by providing a simple interface for monitoring HRV data and accessing relaxation resources, making it a comprehensive tool for anxiety management.

5.2.1. Applications in Preventative Care

By managing anxiety symptoms effectively at home, the device can reduce the need for frequent medical consultations and treatments, thereby cutting healthcare costs. Also, early detection of anxiety can prevent more severe mental health issues, offering a proactive approach to mental health.

A potential for telemedicine integration may also be discussed as the data by the wristband can potentially be shared with healthcare providers, facilitating remote monitoring. Further, when used with traditional therapies, such as cognitive-behavioral therapy or medication, it offers a holistic approach to anxiety management.

5.2.2. Further Applications

PD patients often struggle with sleep-related issues as part of their condition [20]. Incorporating vibration therapy through this device as an example, might offer a non-pharmacological option to enhance sleep quality. The premise of this device is to retrain the nervous system to adapt to stress more effectively over time, potentially leading to better sleep patterns. An ongoing sleep study involving the Apollo wearable, another wearable device using the principles of vibration therapy, has shown promising results, with users reporting up to 30 minutes more sleep each night, and improvements in deep sleep and REM sleep when the device is used consistently [21].

Non-invasive therapies like vibration therapy offer a complementary strategy to traditional treatments, potentially mitigating sleep issues and enhancing well-being in Parkinson's disease without the need for additional medication.

5.3. Advantage of the Device in Reducing Anxiety

The device designed to monitor and respond to changes in HRV offers several advantages in reducing anxiety, and leveraging technology to provide real-time, personalized interventions. Below is an outline highlighting the key advantages of this device in managing and reducing anxiety:

- **Real-Time Monitoring of Physiological Stress Indicators:** The device continuously monitors HRV which is a key physiological indicator of stress and emotional states. Real-time monitoring allows for immediate detection of stress or anxiety onset.
- **Automatic Stress Intervention Through Vibration Feedback:** Upon detecting a deviation in HRV from the normal threshold, indicating increased stress or anxiety, the device automatically initiates a gentle vibration. This tactile feedback is designed to bring the user's attention to their current stress level, encouraging immediate relaxation techniques.
- **Encouragement of Mindfulness and Breathing Exercises:** The vibration feedback serves as a prompt for the user to engage in mindfulness or breathing exercises, proven strategies for reducing anxiety. It effectively bridges the gap between the recognition of stress and the action taken to alleviate it.
- **Personalization and Adaptation Over Time:** The device adapts to the individual user's baseline HRV levels over time, offering personalized monitoring and feedback. This personalization ensures that the interventions are appropriately timed and relevant to the user's unique physiological responses to stress.
- **Accessibility and Ease of Use:** Designed for continuous wear, the device ensures that users have constant access to anxiety management resources and tools without disrupting their daily routines. The non-invasive nature and ease of use make it a practical solution.

6. LIMITATIONS

While the anxiety-detecting wristband device presents a novel approach to managing anxiety, particularly in PD patients, it is important to acknowledge the limitations in its current design and development phase. The limitations provide scope for future improvements and ensure a realistic understanding of the device's capabilities at this stage.

6.1. Lack of Extensive Patient Testing

One of the primary limitations is the lack of comprehensive patient testing. Although preliminary tests may indicate potential benefits, without extensive clinical trials, the efficacy of the device in real-world scenarios remains unverified. Additionally, the variability in responses to vibration therapy among different individuals, especially those with varying severities of Parkinson's Disease, is not well understood.

6.2. Device Specific Limitations

The absence of thorough testing also means that possible side effects or discomfort caused by prolonged use of the wristband have not been adequately assessed. Furthermore, the precision of HRV monitoring, crucial for the device's functionality, needs to be validated through extensive testing, especially in various environmental conditions and during different physical activities.

These limitations highlight the need for further development, especially regarding patient testing, to fully understand and optimize its efficacy and usability.

7. FUTURE OBJECTIVES

Building on the current design and acknowledging its limitations, the future objectives for the anxiety-detecting wristband device are centered around comprehensive clinical testing, refining the design based on feedback, and securing patent protection.

7.1. Comprehensive Clinical Trials

The next phase of research involves conducting extensive clinical trials to validate the efficacy and safety of the wristband in managing anxiety, particularly in PD patients. The trial will involve a diverse group of participants to assess the device's effectiveness across different severities of PD and various demographic groups. Key outcomes will include changes in anxiety levels, patient-reported comfort, device wear ability, and any side effects or adverse reactions. It will also be ensured that the trials are conducted according to health regulatory standards.

7.2. Securing Patent Protection

The development of this device offers several innovative aspects that could be potentially patented under Canadian patent law. Specifically, the combination of HRV monitoring and vibration therapy in a wearable format is a novel approach. Based on the Canadian Patent Act, Section 2, patent claims may focus on the unique method of detecting anxiety based on physiological data and delivering a therapeutic response [22]. Additionally, specifics regarding the application of vibration therapy, such as the intensity, frequency, and location relative to the median nerve, could form a substantial part of the patent application based on Section 28.2 in the Canadian patent act [23].

8. CONCLUSIONS

In conclusion, this paper has presented the design and development of an innovative anxiety-detecting wristband device, tailored specifically for PD patients, but with potential applications to a broader range of anxiety-related conditions. The device uniquely integrates HRV monitoring with vibration therapy applied near the median nerve, complemented by a user-friendly mobile application displaying real-time HRV data and providing relaxation resources.

The initial design and prototype suggest this non-invasive approach could greatly improve the management of anxiety symptoms. However, as outlined in the limitations section, further development is required, and comprehensive clinical trials are essential to validate the efficacy and safety of the wristband in a real-world setting.

This research contributes to the evolving landscape of medical technology regarding anxiety management and in essence, the ergonomic design, ease of use, and integration of wearable technology with digital health tools aim to align well with current trends in patient-centered healthcare and digital medicine.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.

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APPENDIX

Arduino algorithm to run the program and obtain the heartrate data is as follows:

```
/*  Getting_BPM_to_Monitor prints the BPM to the Serial Monitor, using the least lines of code and PulseSensor Library.
*  Tutorial Webpage: https://pulsesensor.com/pages/getting-advanced
*
--------Use This Sketch To------------------------------------------
1) Displays user's live and changing BPM, Beats Per Minute, in Arduino's native Serial Monitor.
2) Print: "♥ A HeartBeat Happened!" when a beat is detected, live.
2) Learn about using a PulseSensor Library "Object".
4) Blinks LED on PIN 13 with user's Heartbeat.
--------------------------------------------------------------------*/

#define USE_ARDUINO_INTERRUPTS true    // Set-up low-level interrupts for most acurate BPM math.
#include <PulseSensorPlayground.h>     // Includes the PulseSensorPlayground Library.

//  Variables
const int PulseWire = 0;       // PulseSensor PURPLE WIRE connected to ANALOG PIN 0
const int LED13 = 13;          // The on-board Arduino LED, close to PIN 13.

//@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
const int vibrationpin = 3;
//@@@@@@@@@@@@@@@@@@@@@@@@@@@@

//THIS VARIABLE CONTROLS HOW MUCH PRESSURE YOU CAN PUT
int Threshold = 550;           // Determine which Signal to "count as a beat" and which to ignore.
                               // Use the "Gettting Started Project" to fine-tune Threshold Value beyond default setting.
                               // Otherwise leave the default "550" value.

PulseSensorPlaygroundpulseSensor;  // Creates an instance of the Pulse Sensor Playground object called "pulseSensor"
void setup() {
  Serial.begin(9600);          // For Serial Monitor

  // Configure the PulseSensor object, by assigning our variables to it.
  pulseSensor.analogInput(PulseWire);
  pulseSensor.blinkOnPulse(LED13);       //auto-magically blink Arduino's LED with heartbeat.
  pulseSensor.setThreshold(Threshold);

//@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
  pinMode(3, OUTPUT);
//@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
  // Double-check the "pulseSensor" object was created and "began" seeing a signal.
   if (pulseSensor.begin()) {
    Serial.println("We created a pulseSensor Object!");  //This prints one time at Arduino power-up,  or on Arduino reset.
```

```
  }
}
void loop() {

 int myBPM = pulseSensor.getBeatsPerMinute();   // Calls function on our pulseSensor object that returns BPM as an "int".
                                                // "myBPM" hold this BPM value now.
//@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
 if (myBPM >= 90){
  //digitalWrite(vibrationpin, HIGH);
  digitalWrite(vibrationpin, LOW);
  //delay(1000);
 }
 else
 {
  //digitalWrite(vibrationpin, LOW);
  digitalWrite(vibrationpin, HIGH);
  //delay(1000);
 }

//@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
if (pulseSensor.sawStartOfBeat()) {              // Constantly test to see if "a beat happened".
 Serial.println("♥ A HeartBeat Happened !"); // If test is "true", print a message "a heartbeat happened".
 Serial.print("BPM:");                          // Print phrase "BPM: "
 Serial.println(myBPM);                         // Print the value inside of myBPM.
}
  delay(20);                       // considered best practice in a simple sketch.
```