Grant Proposal

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Institution: University of Colorado Boulder
Program: Mechanical Engineering Undergraduate Student
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Project Title: Development of a Visual and Auditory Cueing Belt to Improve Gait Fluidity in Parkinson's Disease

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Abstract

Parkinson's disease (PD) is a progressive neurodegenerative disorder that impairs the nervous system's ability to control movement, often leading to slowed walking, short shuffling steps, and freezing of gait (FOG). These symptoms severely reduce mobility and independence. This project proposes the development of a wearable gait cueing belt that uses laser-based visual cueing and auditory rhythmic feedback to assist individuals with Parkinson's in achieving more fluid, stable gait patterns.

The system integrates a gimbal-mounted laser module, microcontroller, and gyroscope to project dynamic visual cues onto the ground in front of the user, synchronized to their movement. A connected mobile app and smartwatch interface will monitor gait data to predict freezing episodes and adaptively trigger cues when needed. This device aims to provide an affordable, non-invasive alternative to existing gait rehabilitation technologies by combining evidence-based neuroscience with practical mechanical design.

Background and Significance

Parkinson's disease affects over 10 million people worldwide, with gait disturbances being among the most debilitating motor symptoms (National Institute of Neurological Disorders and Stroke [NINDS], 2025). The disease results from degeneration of neurons and abnormal accumulation of *Lewy bodies*, disrupting basal ganglia circuits responsible for coordinated movement (Roodveldt, 2024). These neurological deficits lead to bradykinesia, rigidity, tremor, and impaired motor timing, contributing to gait freezing and loss of mobility (Dorsey et al., 2024).

Research has shown that external cueing techniques such as visual, auditory, or tactile stimuli that provide external timing or spatial reference can bypass damaged neural pathways and restore rhythmic movement. Systematic reviews indicate that auditory rhythmic cueing significantly improves stride length and gait velocity (Ghai et al., 2018), while visual cues, such as floor markings or projected laser lines, help initiate movement and maintain step length (Nieuwboer et al., 2007). Combining these modalities can yield additive benefits in both step symmetry and walking speed (Cosentino et al., 2023).

Despite these promising results, access to cueing-based rehabilitation tools remains limited. Many devices are expensive or confined to clinical settings. The proposed Parkinson's Gait Cueing Belt addresses this gap by providing a portable, data-driven, and affordable assistive device for everyday use.

Proposed Solution and Design

The Parkinson's Gait Cueing Belt integrates mechanical, electronic, and computational subsystems to deliver synchronized visual and auditory cueing:

- **Laser Projection and Gimbal Assembly:** The belt houses dual laser diodes mounted on a servo-controlled gimbal that projects a bright horizontal line on the ground approximately one stride length ahead of the user. The position of each diode on the belt will be adjustable, allowing the user to position the diodes directly on top of each hipbone. The position of each diode will allow for optimal projection angle without the user's body interfering. This projection provides a consistent spatial goal for the user to step over, improving stride initiation and rhythm.
- **Microcontroller and Gyroscopic Feedback:** A microcontroller (Arduino Nano 33 IoT or similar) interfaces with an inertial measurement unit (IMU) gyroscope. As the user moves, the gyroscope continuously detects angular velocity and body orientation, allowing the controller to adjust gimbal rotation to keep the laser fixed relative to the walking surface. This will allow the user to physically step over the projection.
- **Smartwatch and Mobile App Integration:** The belt communicates via Bluetooth with a mobile application linked to a smartwatch (e.g., Apple Watch or Fitbit). Using real-time accelerometer and heart-rate data from connected devices, a lightweight machine-learning model will learn the user's gait patterns and predict periods of high freezing risk. The device can then automatically activate laser or rhythmic auditory cues at those times.
- **Auditory Cueing Feature:** Future iterations will integrate auditory cues, proven to increase gait velocity and reduce variability (Wang et al., 2022).

Objectives

1. **Design and prototype** a wearable belt that projects a stable, ground-fixed visual cue via gyroscopic control.
2. **Integrate data acquisition** from smartwatch sensors to record gait patterns and freezing events.
3. **Develop a predictive cueing algorithm** capable of triggering cue activation during anticipated freezing episodes.
4. **Evaluate device efficacy** by testing gait parameters (velocity, stride length, cadence) in simulated Parkinsonian gait trials or volunteer testing under IRB guidance.

Expected Outcomes and Impact

This project seeks to demonstrate that a portable, self-adjusting cueing belt can:

- Improve walking fluidity and reduce freezing episodes in individuals with Parkinson's disease.
- Offer a **cost-effective alternative** to high-cost rehabilitation systems such as peripheral electrical stimulation or treadmill-based cueing.
- Provide **personalized cue delivery**, improving adherence and real-world functionality.

If successful, this technology could directly enhance daily mobility and independence for Parkinson's patients, while also serving as a research tool for clinicians studying the neuro-mechanics of gait cueing. The system's modular architecture allows future integration of vibrotactile or haptic feedback for multi-sensory rehabilitation.

Feasibility and Future Development

Initial component design and modeling will be completed using CAD and embedded systems simulation. Prototype testing will be conducted in controlled environments, with potential collaboration through local physical therapy clinics for pilot evaluation. Estimated cost for a functional prototype is under $250, making it viable for large-scale clinical and consumer adaptation.

Future phases will include refinement of the predictive cueing algorithm, extended user testing, and integration of rechargeable battery and wireless firmware updates. The goal is to establish a foundation for eventual FDA Class I assistive device approval.

Letter of Support

To the NIBIB DEBUT Challenge Review Committee:

I am writing to provide strong support for Andrew's application to the National Institute of Biomedical Imaging and Bioengineering (NIBIB) DEBUT Challenge. As Program Manager for NSF I-Corps Hub West, I have had the opportunity to evaluate Andrew's innovative medical device project developed through the mechanical engineering partnership program between Colorado Mesa University and the University of Colorado, Boulder.

Andrew's unique medical device demonstrates exceptional promise for addressing critical healthcare needs while showcasing the innovative engineering capabilities fostered through this collaborative academic partnership. His technical approach and commitment to developing market-relevant solutions align perfectly with both the DEBUT Challenge objectives and our I-Corps mission of translating research into commercial impact.

I am pleased to confirm that Andrew will be invited to participate in our upcoming Regional NSF I-Corps Customer Discovery programming offered through NSF I-Corps Hub West. This intensive program will provide Andrew with essential entrepreneurial training, customer discovery methodologies, and market validation techniques that will significantly enhance the commercial potential of his medical device innovation.

Andrew's participation in our upcoming I-Corps programming, combined with the strong engineering foundation from his academic partnership, positions him exceptionally well for success in the DEBUT Challenge and subsequent commercialization efforts.

We are committed to supporting Andrew throughout his entrepreneurial journey and believe his medical device innovation has significant potential for positive healthcare impact. I strongly encourage your favorable consideration of his DEBUT Challenge application.

Please feel free to contact me if you require any additional information regarding our support for Andrew or our I-Corps programming.

Sincerely,

Daniel Marshall Program Manager NSF I-Corps Hub West

NIBIB DEBUT Certification Form

National Institute of Biomedical Imaging and Bioengineering

DEBUT

CERTIFICATION FORM

Instructions:
Each and every member of a Student Team participating in the DEBUT Challenge must read this Certification Form and complete it by providing the information requested in items 1-3 below, and signing and dating where indicated. A Student Team can include only one Certification Form with its entry, which will be submitted by one member of the Student Team appointed to do so by that Student Team (i.e., "Team Captain" of that Student Team). Entries that fail to include a completed Certification Form will be disqualified from the Challenge.

FOR FURTHER INFORMATION CONTACT: Dr. Dave Gutekunst at (301) 402-5069 or dave.gutekunst@nih.gov

1. **Project Title:** Parkinson's Gate Queuing Belt

2. **Do you wish your entry to be also considered for prizes offered by VentureWell?**
   See http://venturewell.org/students/debut *for a description of these prizes and rules for competing for them.*
   ☒ **Yes** ☐ **No**

3. I have read and understand the NIBIB DEBUT Challenge Rules ("Rules") located at

   http://www.nibib.nih.gov/training-careers/undergraduate-graduate/design-biomedical-undergraduate-teams-debut-challenge

   I hereby agree to abide by such Rules.

   I hereby agree to assume any and all risks and waive claims against the Federal Government and its related entities, except in the case of willful misconduct, for any injury, death, damage, or loss of property, revenue, or profits, whether direct, indirect, or consequential, arising from participation in this prize challenge, whether the injury, death, damage, or loss arises through negligence or otherwise.

   I hereby agree to indemnify the Federal Government against third party claims for damages arising from or related to Challenge activities.

   I hereby grant NIBIB an irrevocable, paid-up, royalty-free, nonexclusive worldwide license to post, link to, share, and display publicly the entry on the Web, newsletters or pamphlets, and other information products.

References

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