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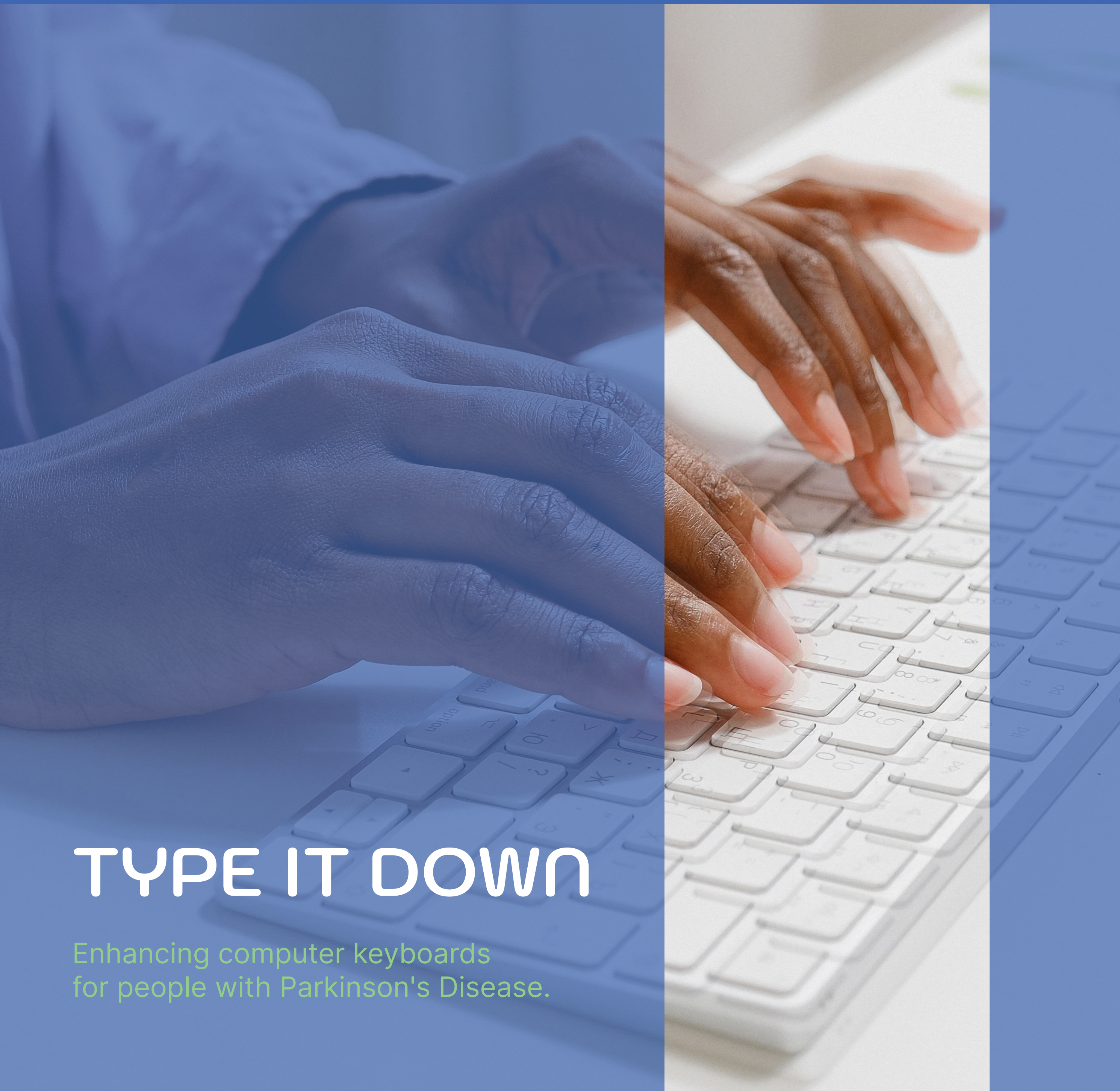

TYPE IT DOWN

Enhancing computer keyboards
for people with Parkinson's Disease.

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Abstract

This project focuses on improving computer keyboard interaction for people with Parkinson's Disease (PD), specifically addressing the symptom of bradykinesia, which causes slowed movement and impairs fine motor skills. The objective is to explore the integration of cueing techniques—external stimuli such as auditory prompts, visual cues, and haptic feedback—to assist people with PD in initiating and executing movements more effectively.

Adopting a user-centered design approach and involving actual users throughout the research and testing phases, the project investigated various concepts to enhance the ergonomics and functionality of keyboards for people with Parkinson's. Multiple prototypes were developed and tested through focus groups, providing valuable feedback that guided the refinement of the design.

The final design, called OnCue, features a modular system comprising an ergonomic keyboard specifically tailored to users' needs, with integrated haptic feedback, visual cues, and haptic cuffs. A key feature of the design is its customizability, allowing the system to adapt to individual needs as symptoms fluctuate daily. The goal is to reduce frustration and improve the quality of life for people affected by Parkinson's. This project demonstrates the potential of adaptive technologies to significantly enhance well-being and foster greater independence for users.

Preface

This thesis marks the culmination of my academic journey, which began in Milan with a Bachelor's in Product Design, enriched by three and a half years of professional experience, and followed by the decision to explore new disciplines and methodologies abroad. Pursuing a Master's in Integrated Product Design here in the Netherlands has allowed me to expand my horizons and approach design from a broader perspective.

As I reach the end of this Master's program, I am deeply grateful for the personal and professional growth I have experienced throughout these years. I can confidently say that I have been changed, enriched by encounters with different cultures, approaches, knowledge, and perspectives.

My goal was to complete this journey with a project of real significance, and I am proud of the choice I made. The realization that something as fundamental as a computer keyboard can become a barrier for people with Parkinson's disease in an increasingly digital world was the driving force behind this work. I firmly believe that design is a powerful tool for addressing complex challenges, and when we prioritize people and communities over profit or consumerism, we can create meaningful and impactful solutions.

Like any journey that comes with its share of obstacles, challenges, and learning experiences, this graduation project was no exception. We are still at the beginning of the journey to truly improve the lives of people with Parkinson's, but I am proud to have contributed to laying the groundwork.

I would like to extend my gratitude to Dr. Marco Rozendaal, Dr. Gert Pasman, and Dr. Erik Prinsen for their guidance, valuable feedback, and for the opportunity to work on this project.

A special thank you goes to my partner Matteo for his unwavering support and belief in my abilities, and to my parents, Elisabetta and Romano, my sister Margaret, and my entire cherished family and friends, whose presence and encouragement have been constant throughout this journey. As I reach the end of this academic path, I dedicate this thesis to my niece Eleonora, who is new to the world, and to whom I hope will one day discover a passion as strong as design has been for me.

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1. PROJECT INTRODUCTION

1.1 Introduction

The project's domain is design for health and social well-being, focusing on Parkinson's Disease (PD) and its impact on individuals' daily lives, particularly their interaction with a common tool: the computer keyboard. In today's increasingly digital age, the computer keyboard is not just a tool but a gateway to essential activities such as working, accessing social networks, and banking.

Parkinson's Disease is a global concern, affecting 8.5 million people worldwide. People with PD face significant challenges in executing sequential movements and experience delayed reactions when using a physical keyboard, leading to frustration and avoidance behaviors. This project, funded by ParkinsonNL—an independent organization dedicated to raising funds for research, innovation, and education in the Netherlands (ParkinsonNL, n.d.)—aims to enhance their interaction with computer keyboards by specifically addressing the symptom of bradykinesia, which causes slowed movement and impairs fine motor skills.

The project explores the integration of "cueing techniques," which use external cues such as auditory prompts and haptic feedback to aid in initiating and executing movements. By embracing a user-centered approach that actively involves the target group, the goal is to enhance their quality of life, foster social engagement, and empower individuals.

1.2 Project Approach and Method

The project approach follows the principles of User-Centered Design (UCD), emphasising the user perspective to develop valuable and usable products, while also integrating the Double Diamond Method as a guiding framework.

This method comprises four key stages: Discover, Define, Develop, and Deliver. The overall concept is to diverge during the exploration phases and converge during the refinement phases.
The Discover phase entails extensive user research, focus group, literature reviews on Parkinson's Disease, needs analysis, examination of existing technologies, and cueing techniques research.
Transitioning to the Define phase, insights are synthesised to establish clear goals and requirements, crucial for improving comprehension and guiding later stages.
In the Develop phase, both conceptualisation and prototyping occur, progressing from low to high fidelity, informed by rigorous testing and user feedback.
Lastly, the Deliver phase focuses on user evaluation, refining the final concept and prototype based on feedback, and offering recommendations for future enhancements.

Methods applied during the project:

DISCOVER PHASE
- questionnaire
- focus group

DEFINE PHASE
- design goal
- list of requirements

DEVELOP & DELIVER PHASE
- morphological chart

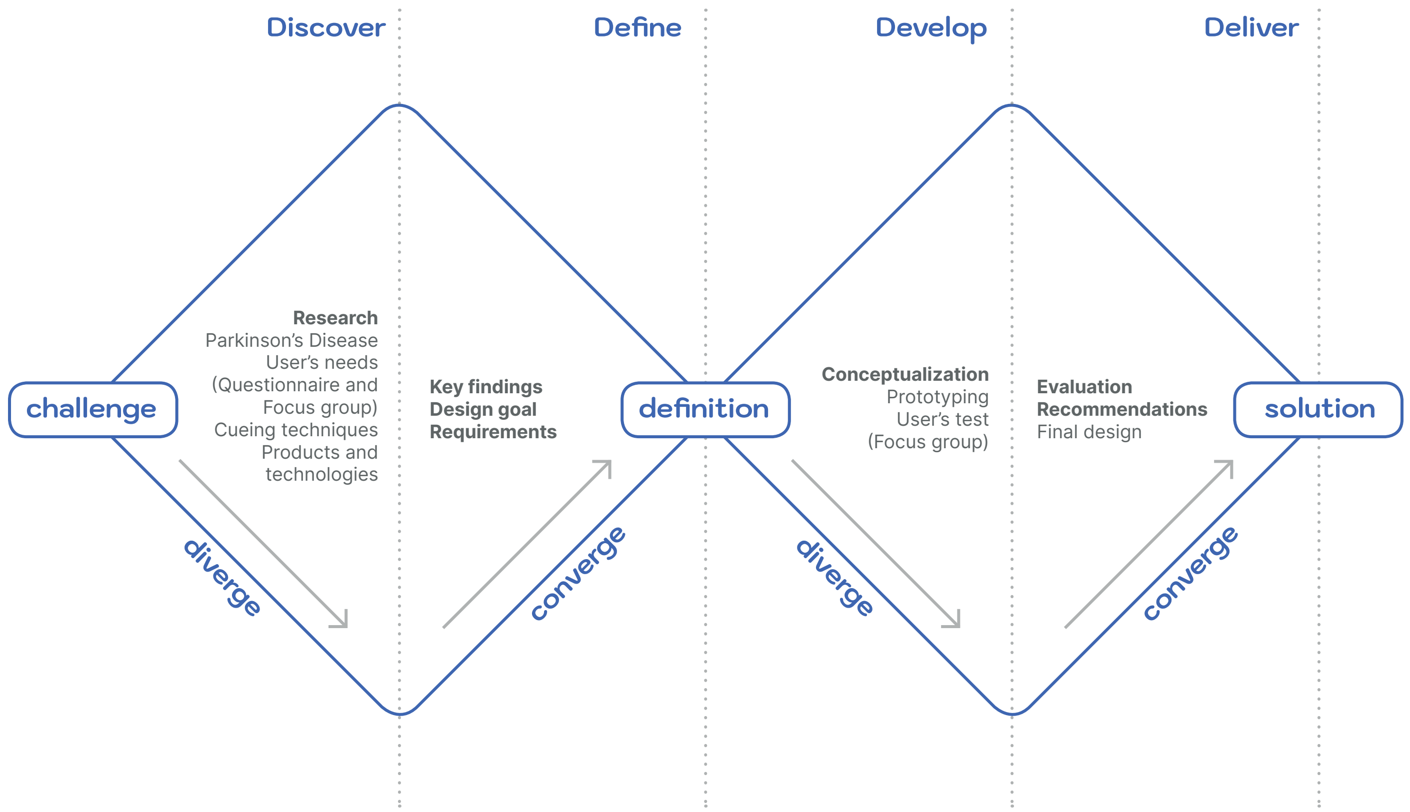


Fig. 1 Double Diamond Method

2. PARKINSON'S DISEASE

2.1 Introduction to Parkinson's Disease

Currently, there are about 53.000 individuals in the Netherlands diagnosed with Parkinson's Disease (PD). Worldwide, over 8.5 million individuals live with PD and the prevalence has doubled in the past 25 years.

PD is a neurological condition that leads to difficulties with movement, mental health issues, disrupted sleep, pain, and other health complications. Common symptoms comprise tremors, painful muscle contractions, and speech impairments. As the disease advances, individuals may encounter challenges in walking, speaking, or performing basic tasks. Many people with PD also develop dementia. This disease results in high rates of disability and the need for care. PD gets worse over time and there is no cure yet. Nevertheless, therapies, assistive devices, and medications are available to alleviate symptoms and enhance the quality of life for those with PD (World Health Organization: WHO & World Health Organization: WHO, 2023).

53.000

Individuals in the Netherlands diagnosed with Parkinson's Disease

8.5 million

Individuals worldwide diagnosed with Parkinson's Disease

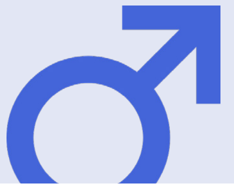
2.2 Who is more likely to develop Parkinson's Disease

Parkinson's disease is more prevalent among individuals with certain risk factors related to age, gender, heredity, and environmental exposure. However, the precise cause remains elusive, with most cases being sporadic.
On average, symptoms manifest around the age of 70, though a small percentage experience early-onset disease before the age of 50. Men are at a higher risk compared to women. Moreover, a familial history of PD increases the risk, with 15-25% of patients having affected relatives, with some cases attributable to particular genetic mutations. Lastly, environmental factors contribute to Parkinson's risk. Exposure to pesticides, air pollution, and solvents may heighten the likelihood of acquiring the disease. Thus, it is the combination of various risk factors that can lead to its onset (Parkinson's Disease, n.d.).

Typically, symptoms appear around the age of 70, but a minor proportion of individuals develop early-onset disease before reaching 50.

70

Men face a higher likelihood of developing the condition compared to women.



A family history of PD elevates the risk, with 15-25% of patients having relatives who are also affected. In some instances, this can be linked to specific genetic mutations.

Being exposed to pesticides, air pollution, and solvents can increase the risk of developing the disease.

2.3 How is Parkinson's Disease diagnosed

Diagnosis primarily relies on a detailed review of medical history and a neurological examination. Non-instrumental screening typically involves assessing the subject's overall condition using standardised scales such as the MDS-UPDRS (Movement Disorder Society-Sponsored Revision of the Unified Parkinson's Disease Rating Scale) (Iakovakis et al., 2018). This tool comprehensively evaluates various aspects of Parkinson's, including non-motor and motor experiences of daily living and motor complications (MDS-Unified Parkinson's Disease Rating Scale (MDS-UPDRS), n.d.) However, this method requires a movement disorders specialist and in-person clinical examination. Various assessments, including blood tests, laboratory analyses and brain scans, are conducted to rule out other conditions that might be responsible for the symptoms.
In exceptional cases, where individuals have a clearly hereditary form of PD, researchers can examine for known gene mutations to assess an individual's risk of developing the disease. In conclusion, at the moment, there is not a singular test for definitively diagnosing Parkinson's Disease (Parkinson's Disease, n.d.).

2.4 Symptoms

Parkinson's is a progressive disease that presents a diverse range of symptoms across individuals. While this graduation project focuses on bradykinesia, it is important to provide an overview of Parkinson's symptoms to understand the disease's complexity and ensure comprehensive design considerations. Parkinson's symptoms can be categorized into two main groups: motor symptoms and non-motor symptoms.

Motor symptoms are observable externally and serve as the first diagnostic indicators. The four main motor symptoms of PD include muscle stiffness, slowness of movement (bradykinesia), postural instability, and resting tremor, which involves involuntary shaking in a finger, hand, or limb while at rest, disappearing during intentional movement. Although tremors often contribute to the initial diagnosis, they do not affect all individuals with Parkinson's. Not all Parkinson's patients experience all four motor symptoms, but slowness of movement is consistently present.

Postural instability, such as freezing of gait issues and difficulties in maintaining balance and coordination, may arise at any stage of the disease but become more prevalent as it progresses.
The secondary set of symptoms falls under the non-motor category. These non-motor symptoms are often referred to as the hidden symptoms of Parkinson's because they are not externally visible. Despite their invisibility, they can significantly impact the quality of life for individuals with Parkinson's and their families. Non-motor symptoms may include autonomic dysfunction, mood changes, and cognitive impairments.
Regarding autonomic dysfunction, Parkinson's can disrupt the body's automatic or involuntary functions. This may include orthostatic hypotension (a drop in blood pressure when changing positions, such as standing from sitting, which can cause lightheadedness, dizziness, or fainting), sexual issues such as erectile dysfunction in men and decreased libido or pain in women, excessive perspiration, urinary problems, and constipation. PD can also influence mood and cognitive capacities. Individuals may experience a broad spectrum of memory or cognitive challenges, ranging from mild difficulties in multitasking and focus that do not impede daily routines to more severe issues that impact work, daily functioning, and social engagement, potentially culminating in dementia. Additionally, they might confront apathy, depression, anxiety, and psychosis, which can manifest as visual hallucinations and the development of unfounded, often paranoid, beliefs. Other physical changes include drooling due to decreased swallowing, which leads to a buildup of saliva, and swallowing difficulties that can cause choking, coughing, and throat clearing when eating and drinking. Speech issues are also common, such as speaking softly and monotonously, as well as occasional slurring or mumbling of words. Additionally, individuals may experience bodily pain, alterations in skin texture (such as oily or dry skin), and an elevated risk of melanoma. Other symptoms include loss of the sense of smell, fluctuations in weight, dry eyes, double vision which can make reading difficult, and sleep disturbances (Symptoms, n.d.).

2.5 Bradykinesia

Bradykinesia is one of the cardinal symptoms in PD. It is defined as "slowness of initiation of voluntary movement with progressive reduction in speed and amplitude of repetitive actions". It is known in motor physiology as the sequence effect (Hasan et al., 2019).

The sequence effect refers to the gradual worsening of repetitive movement performance over time, affecting abilities such as speaking, limb movement, and walking. This decline can make it difficult to communicate, use objects, or walk without experiencing freezing episodes. The issue stems from the brain's struggle to maintain smooth and consistent movement patterns, rather than from physical muscle fatigue, and it is primarily associated with Parkinson's disease. In limb bradykinesia, the sequence effect manifests as a gradual decline in the range and pace of movements, making tasks like writing, typing, and manipulating objects (such as tools or buttons) increasingly challenging (Kehnemouyi et al., 2023).

Assessment tools for bradykinesia can be split into two categories: subjective (clinical rating scales) or objective (technology-based tools). Clinical scales like the MDS-UPDRS (described in paragraph 2.3) evaluate bradykinesia based on factors such as speed and amplitude reduction, hesitations, motor arrests, and fatigue. However, this method is not fully reliable due to inter-rater variability. On the other hand, technology-based tools (machinery and devices developed from scientific knowledge) offer objective, quantifiable scores of motor dysfunction, enhancing accuracy and consistency in assessment during clinical visits or at home (Hasan et al., 2019).
Bradykinesia stems from a disruption in communication between the basal ganglia and cortical areas that control motor functions. The basal ganglia are clusters of neurons deep in the brain that play a key role in regulating movement. When this communication breaks down, it leads to difficulties in starting movements, longer reaction times, and abnormal brain activity before executing actions. To compensate, the brain boosts activity in lateral premotor areas and utilizes sensory cues and focused attention to enhance movement. This compensation results in reducing the ability to perform multiple tasks simultaneously and difficulty in task switching. So, when complexity is added to movements, such as repeating or combining them with other tasks, bradykinesia becomes more prominent, as evidenced by smaller and slower movements, leading to fatigue. Additionally, secondary factors like muscle weakness, rigidity, tremor, movement variability, and bradyphrenia (slowed thought) can further impact bradykinesia in PD. Hasan et al. suggest that people with Parkinson's disease may rely on external cues, such as visual or auditory prompts, or heightened attention to aid in movement execution. These strategies can partially alleviate motor difficulties, allowing for more efficient movement performance. This supports the exploration of cueing techniques to enhance computer keyboard interaction, as discussed in chapter 4 (Berardelli, 2001).

Bradykinesia:

> **"Slowness of initiation of voluntary movement with progressive reduction in speed and amplitude of repetitive actions"**
>
> *(Hasan et al., 2019)*

3. USER'S PERSPECTIVE

This chapter focuses on individuals diagnosed with Parkinson's disease and how it affects their daily lives, particularly in terms of interacting with computer keyboards. It explores the impact of the disease both personally and practically, enhancing our understanding of user needs. The literature has been reviewed, and a questionnaire was conducted, gathering 19 responses.

3.1 How bradykinesia influences keyboard interaction

This paragraph presents the results of a study by Panyakaew et al., titled "The Many Faces of Bradykinesia in Parkinson's Disease: A Quantitative Analysis from a Keyboard Typing Test," which aimed to examine differences in typing performance between Parkinson's Disease patients and healthy individuals. The study sought to understand how bradykinesia affects typing efficiency. Below are the identified variables and related results that highlight the challenges faced by people with PD:

__1. Frequency:__ The total number of keystrokes made by participants during typing tasks.

__2. Typing Velocity:__ The speed at which participants type, measured in keystrokes per second.

Patients diagnosed with PD, particularly when using their less adept hand, demonstrated a significant decrease in typing frequency and speed compared to individuals without PD. This decrease was observed in both side-by-side and far-reach typing tasks, where keys are positioned further apart.

__3. Accumulative Typing Error:__ The total number of errors made by participants during typing tasks.

__4. Error Rate:__ The rate at which errors occur during typing tasks, measured in errors per second.

__5. Accumulative Repetition of Typing Keys:__ The total number of times participants repeat typing the same keys during typing tasks.

__6. Repetition Rate:__ The rate at which key repetitions occur during typing tasks, measured in repeated keystrokes per second.

PD patients exhibited significantly higher accumulative typing error, error rate, accumulative repetition of typing keys, and repetition rate compared to individuals without PD, particularly observed in side-by-side typing. The repetition rate suggested a potential occurrence of freezing.

__7. Digraph Duration:__ The average time it takes to type two consecutive letters sequentially during typing tasks, measured in seconds.

__8. Digraph Rate:__ The rate at which digraphs (consecutive pairs of typed letters) are typed during typing tasks.

PD patients also demonstrated longer durations to type consecutive letters (digraph durations) and a higher digraph rate.

In conclusion, the study illuminated the characteristics of bradykinesia in Parkinson's disease (PD), showcasing a decline in both the frequency and amplitude, alongside a progressive increase in movement errors and instances of freezing during repetitive limb motions (The Many Faces of Bradykinesia in Parkinson's Disease : The Quantitative Analysis From a Keyboard Typing Test - MDS Abstracts, 2020).

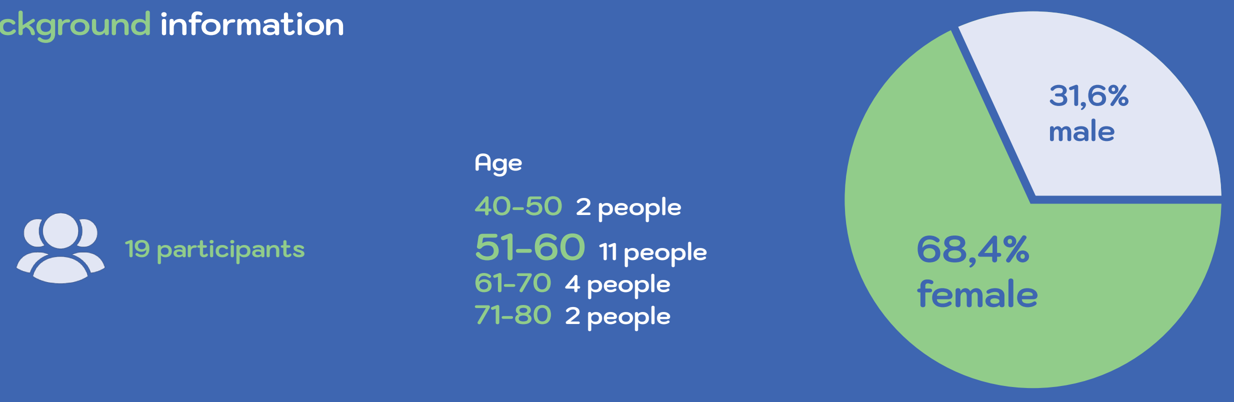
3.2 How bradykinesia influences people's quality of life

As previously mentioned, 19 individuals were surveyed for this project to gain insights into their experiences with keyboard use, focusing on their feelings and perceptions. (Processed results can be found on pages 17 to 21, while complete answers are available in Appendix A.) The results confirmed that people with Parkinson's disease often struggle with sequential movements and delayed reaction times, leading to avoidance behaviors. Of those surveyed, the majority were in the early stages of Parkinson's, with 30% in the first stage and 47% in the second. Notably, only two respondents reported no difficulties using a computer keyboard. This underscores the significance of the issue, especially since 57% of the participants stated that they use a keyboard daily for several hours.

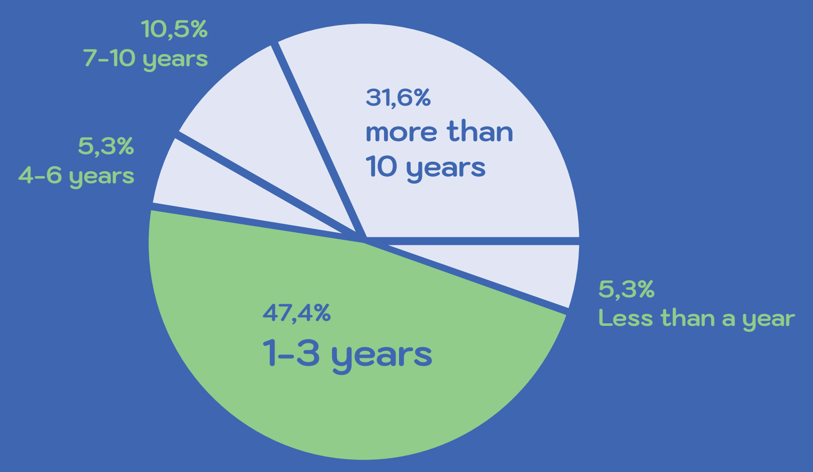
According to our questionnaire, 63% of respondents reported that, in addition to bradykinesia, they also experience other symptoms such as twitching, stiff fingers, and tremors, which further complicate their interactions with keyboards. Respondents expressed that the increasing number of mistakes not only leads to wasted time and energy but also contributes to significant frustration. Feelings of defeat, powerlessness, inadequacy, loneliness, sadness, annoyance, and anger were mentioned by those unable to use the keyboard as desired. The keyboard serves as more than just a tool; it is a gateway to work, social networks, online banking, and shopping. As our world shifts increasingly online, difficulties in accessing these digital spaces can exacerbate negative emotions.
The most common activities reported were typing emails, browsing the web, and writing documents. Despite the prevalence of this problem, only 7 out of the 19 respondents sought features to improve their typing skills. Most tried dictation technology, but it appears that this technology does not yet meet user expectations. When asked how they would like to alter the keyboard's design, respondents' opinions varied widely. Some desired larger keys or more space between them, while one user preferred to keep the current layout. Another suggested using fewer keys, and yet another proposed arranging the keys in alphabetical order. Additionally, suggestions included the use of AI (Artificial Intelligence) and hand supports. These responses highlight the difficulty of determining which changes might improve user experience without experimentation, given the complexity of bradykinesia and other related symptoms.
What users seem certain about is how improving their interaction with the keyboard could significantly enhance their quality of life. The most frequently mentioned benefits included reduced frustration, less time wasted, and increased energy and social contact. Enhancing this interaction could help alleviate the feelings of isolation imposed by the disease. Moreover, with a significant percentage of jobs relying on computers in modern economies (particularly in the service, technology, finance, and education sectors)ensuring easier access to these tools is crucial. One user emphasized that better keyboard interaction would enable them to maintain connections with the world and friends overseas, highlighting the crucial role of digital accessibility.

Questionnaire results:

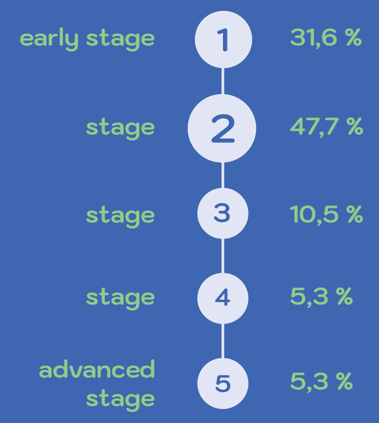
1. Background information



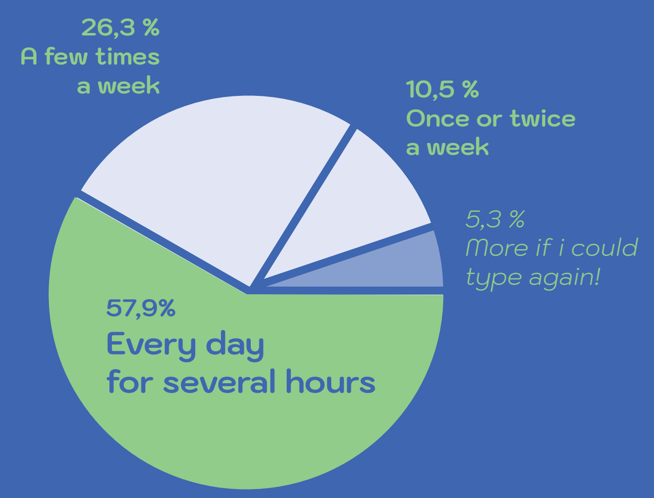
2. How long have you been living with Parkinson's?



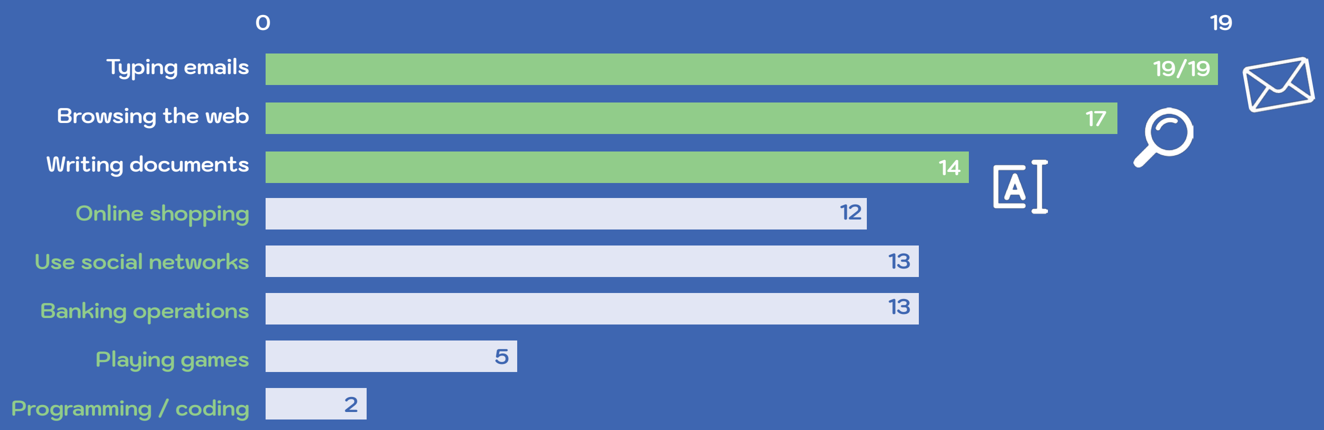
3. What stage of Parkinson's disease are you currently experiencing?



4. How often do you use a computer keyboard?



5. What activities do you usually perform on the computer ?



6. How does bradykinesia (slowed movement) affect your ability to type or use a keyboard?

Only 2 people out 19 replied that they do not have problems so far with using the computer keyboard!

+ time
+ mistakes
+ dictation function
+ tired and frustrated

7. Are there other symptoms (e.g., tremors, stiffness) that also impact your keyboard use?

37% No, only bradykinesia (7/19)

63% I have other symptoms too (12/19)

Twitching

Stiff fingers

Tremors

The harder the keystroke, the harder it is. A soft touch keyboard works best!

8. Can you describe a time when using a keyboard was very challenging?

MEDICATION / off-period
4 people / 19

During the off-period, it is (**mainly on the right**) more difficult to move the fingers properly.

When I'm "off" it's very challenging because I can't move well and have no feeling my hands wouldn't press the right keys.

NOT CHALLENGING
2 people / 19

Not a challenge, still going well.

MENTIONED TASKS / drafting reports, online banking, writing long emais, take notes

Try to **write a book** but I get **frustrated** now. It's making me **lose interest** in the project.

Trying to do **online banking** and using the **number pad** correctly.

Every day of my **work life**. I **cannot take notes** in meetings (I work remotely).

FEELINGS / avoidance behaviour, embarassment

I would **not** really **feel like doing it**, knowing it would take a lot of effort. I would have to answer mails, with quite some text to write. **I tense up more, because my left hand does not function well**. It would not find keys quick enough, which results in my right hand finding the keys to soon and therefore the letters in the words not being in the correct order. **Also my left fingers would 'stick' on keys**, **not moving up fast enough**. Resulting in 'eeeeeeeeeeeeee' or 'ssssssssss' for instance, which I then had to correct. It also means **I can concentrate less** on content, because the functioning of my hand is distracting, as are the mistakes I made.

Before my diagnosis and I started taking C/L I had come to the conclusion I was going to have to look into **dictation software** or **look at finding a job that didn't require me to type**.

Typing in front of lots or people and **twitchy fingers** hit the wrong keys.

one hand functions less than the other

no multi-tasking

9. How did you feel?

Frustrated

Good

Impatient and a bit sad

Very annoying, takes more time, and you start avoiding long texts

Frustrated and defeated

Annoyed

Depressed and frustrated

Debilitated, unprofessional, afraid I'd lose my job

Good

Powerless, inadequate, isolated, lonely

Frustrated by making typing errors and correcting them

Frustrated and angry

Frustrated. I have so much to tell but the typing halts that ability

Frustrated

Okay

Good

Annoying, avoid typing long texts

Frustrated, useless

10. Have you made any adjustments or found any tools that help you use a keyboard more effectively?

YES 7 / 19 people

I use the dictation function of my laptop/phone.

Tried **dictation** but you have to do far more editing afterwards. So that's **discouraging as well**.

Illuminated keyboard.

A **stylus** but it needs to be big and firm.

Soft touch works better.

NO 12 / 19 people

No, **I don't know where to go for help.**

No, I used dictation for a while. That works pretty well, but **still needs a lot of correcting**.

No. Except that I use a mouse and not the touchpad. It is much too sensitive.

11. Do you use any accessibility features or assistive technologies for other Parkinson's symptoms? If so, which ones, and how do they help?

YES 9 / 19 people

Dictation for this typing problem. But I can't use that everywhere. In Word and E-mail, it is pretty good.

Yes, only dictation in Word

DragonSpeak (likely referring to the speech recognition software Dragon NaturallySpeaking)

Siri on my phone. Alexa in my house.

Orthotic insoles.

Music.

Ergonomic mouse, voice program.

Mouse.

A stylus helps accuracy on my phone. My iPad is much easier than using a laptop keyboard.

DBS (Deep Brain Stimulation).

NO 10 / 19 people

No, **I don't know where to go for help.**

No, I used dictation for a while. That works pretty well, but **still needs a lot of correcting**.

No. Except that I use a mouse and not the touchpad. It is much too sensitive.

12. The project is investigating the integration of haptic feedback such as vibration. Would you prefer to use a wearable or a keyboard itself to be designed with built-in haptic feedback?

Wearable
8 people (42.1 %)

Keyboard
13 people (68.4 %)

13. What features would you like to see in a keyboard designed specifically for individuals with Parkinson's?

Are there any specific modifications (e.g., key size, spacing, feedback) that you think would help?

Bigger keys

6/19 people
I don't know!

Same size
I want the same size, really. Because that is what my hands are used to. But feedback may work.

Bigger keys or larger space between keys
Larger spacing between keys or bigger keys so you don't hit 2 or the wrong letters.

Support for hands
No idea, support for the hands to reduce pain and strain in the wrists and arms.

Bigger keys with more space between them and touch screen
Bigger keys with more space between them. Touch screen like an iPad.

Bigger keys and AI
Bigger keys maybe? But then the hand would have to strain too much to reach. It's possible that using AI to see my most frequently occurring mistakes would help?

Larger keyboard

Alphabetical order
Size, keys in alphabetical order. One key functions for capitals.

Less keys
Keys that are easy to press, as few keys as possible.

Different needs

14. How do you believe that a better interaction with the computer keyboard could affect your daily life and overall quality of life?

Eliminate the frustration and feeling of defeat that comes with Parkinson's.

Less frustration, less time wasted, less energy.

It could extend my career and income. Improve confidence and make me less reticent to start the work day.

I keep in touch with the world and my friends overseas and if it was easier to use I wouldn't get so frustrated.

− frustration

− time wasted

+ energy

+ social contact

Complete answers can be found in Appendix A.

4. Cueing techniques

4.1 Introduction to Cueing tehcniques

This project aims to investigate the integration of cueing techniques to assist individuals with Parkinson's disease (PD) in computer keyboard interaction. "Cueing can be defined as using **external stimuli** which provided temporal (related to time) or spatial (related to space) information to facilitate movement initiation and continuation".

Three cueing modalities are widely discussed in the literature: visual, auditory, and somatosensory cueing.

Visual cueing uses visual stimuli. An example of visual cueing is the adoption of lines on the floor to guide movement and mitigate freezing episodes in people with Parkinson's disease (PD).

Auditory cueing employs rhythmic auditory cues, such as metronome beats or music, to synchronise movements and improve gait patterns in those experiencing motor difficulties.

Somatosensory cueing utilises tactile or proprioceptive stimuli, like physical touch or balance exercises, to enhance movement initiation and control by improving body awareness and proprioception (Sweeney et al., 2019).

4.2 Product analysis

A comprehensive research study has been conducted on products designed to address Parkinson's symptoms, specifically focusing on those that integrate cueing techniques. Additional relevant products that served as inspiration, but do not include cueing feedback, are detailed in Appendix B.
Of the nine projects reviewed (pages 25-29), five are currently available on the market, one has been discontinued, and three remain in the concept stage. These products primarily target two common symptoms of Parkinson's disease: tremors and freezing of gait (FOG). The predominant cueing technique utilized in these innovations is somatosensory, specifically haptic feedback. Unfortunately, no keyboards incorporating cueing techniques were identified. These innovative solutions highlight the significant potential of cueing techniques, particularly haptic feedback, to enhance the daily lives of individuals with Parkinson's disease by improving their ability to manage tremors and gait disturbances.

4.3 Haptic feeback as Parkinson's therapy

The concept of using vibrations to address Parkinson's disease dates back to the 19th century. Neurologist Jean-Martin Charcot designed a vibrating chair after noticing his patients experienced temporary relief from symptoms following extended, bumpy carriage and horseback rides. Although Charcot's chair and subsequent vibrating platforms provided some symptom relief, the effects were inconsistent and short-lived.

Recently, Stanford researcher Peter Tass developed a vibrating glove (fig. 8) to alleviate Parkinson's symptoms, such as tremors, stiffness, and bradykinesia, by desynchronizing abnormal neuron activity. The glove delivers vibratory bursts through the fingertips to reset abnormal brain patterns. Clinical trials for the glove are ongoing, aiming to provide a noninvasive treatment alternative (Stanford Medicine, 2024). This treatment offers an alternative to deep brain stimulation (DBS), which, while effective, can have side effects. Coordinated reset (CR) stimulation was designed to reduce abnormal brain activity and connections, aiming for lasting therapeutic effects. Originally developed for DBS, this method has been adapted into vibrotactile CR (vCR) fingertip stimulation using vibratory signals.

Recent studies with PD patients have shown that using vCR for four hours daily for over three months is feasible, has no side effects, and significantly reduces Movement Disorders Society-Unified Parkinson's Disease Rating Scale (MDS-UPDRS) scores. One study found that three months of daily vCR therapy significantly reduced abnormal brain activity. Notably, both studies were performed off medication, supporting the development of a proof-of-concept study for vCR in PD treatment. These results highlight the potential of noninvasive techniques using specialized multi-site stimuli for PD therapy (Vitek et al., 2022).

Haptic vibration has also been explored in virtual reality (VR) rehabilitation using haptic gloves. Studies show that fingertip vibrotactile feedback in VR training improves dexterity in PD patients. Combining haptic feedback with visual and auditory cues enriches the VR experience, boosting interaction, immersion, and engagement, and demonstrating how combining different cues could benefit this graduation projects (van den Eerenbeemt et al., 2020).

Another study supports this technique by exploring the safety and tolerability of a wearable vibrotactile stimulation device for PD. Vibration units were attached to subjects' wrists and ankles using velcro straps, delivering two types of stimulation: high amplitude patterned and low amplitude continuous. High amplitude patterned stimulation involved stronger, rhythmic vibrations, while low amplitude continuous stimulation provided gentler, constant vibrations. The study found that both types of stimulation were safe, well-tolerated, and significantly reduced tremor severity. There was no significant difference between the two methods, suggesting that short durations of vibrotactile stimulation via wearable devices may reduce resting tremor severity in PD patients (Tabacof et al., 2021).

4.4 Effectiveness of cueing

Sweeney et al. explored how cueing techniques have been applied to address a common PD symptom, Freezing of Gait (FoG). FoG is characterised by brief episodes of absent or reduced forward progression of the feet despite the intention to walk. This study is valuable to our research as it demonstrates the application of cueing techniques to alleviate a Parkinson's symptom. The insights gained can be applied further to our project, specifically addressing bradykinesia.
Sweeney et al. pointed out that the effectiveness of cueing techniques to ameliorate FoG remains unclear; however, several studies in the literature provide a clear overview of how people benefit from these techniques. One study suggests that cueing **compensates for defects in the internal rhythm generator** of the basal ganglia, a brain region involved in motor control. By providing external temporal information, such as through auditory, visual, or somatosensory signals, cueing can synchronise movements with an **external rhythm**. Another theory posits that individuals with PD may use **visual cueing** to provide spatial information to **scale and guide movements**, potentially bypassing their defective basal ganglia during gait. Additionally, **cognitive and attentional mechanisms** may play a role in the positive effects of cueing on FoG. Auditory, visual, or somatosensory cues may **shift attention from the FoG to the task of walking**, aiding in conscious movement planning. Furthermore, studies suggest that cueing enhances proprioceptive information processing. **By stimulating proprioceptive inputs** through visual or somatosensory cueing, individuals with PD may **receive enhanced information** on limb position and movement during gait, contributing to improved motor function (Sweeney et al., 2019).

4.5 Key findings

It is now evident that cueing techniques can be beneficial in addressing symptoms of PD. However, insights from Sweeney et al.'s research underscore the importance of considering several key factors when integrating these techniques. When designing interventions aimed at incorporating cueing techniques, it's crucial to consider the following criteria:

1. Continuous delivery of a specific cue may result in undesired outcomes. Research suggests that consistently providing auditory cues, irrespective of the presence of Freezing of Gait (FoG), can lead to habituation in individuals with PD. This habituation over time may reduce the effectiveness of the cues. Therefore, implementing an **on-demand cueing** system could address this concern by providing cues only when needed, potentially alleviating FoG episodes as they occur.

2. Seamless integration of cueing techniques is crucial to prevent individuals from feeling conspicuous. Participants in studies have expressed discomfort with overt cues, such as wearing headphones, highlighting the necessity for subtlety in cueing system design. For instance, participants emphasised the importance of discreet cues to ensure that neither the presence of the system nor the auditory cues themselves draw undue attention.

3. Personalisation plays a pivotal role in cueing interventions, as each individual may have unique timing preferences and differences in completing movement and tasks. Tailoring cueing parameters to suit specific needs and preferences can significantly enhance the effectiveness of the intervention. This personalised approach acknowledges the diverse movement patterns and responses among individuals with PD, thereby optimising the potential benefits of cueing techniques (Sweeney et al., 2019).

4. Haptic feedback has demonstrated proven therapeutic effects. Different studies explored applying haptic feedback not only to the fingertips but also to the wrists, allowing the investigation of its benefits across multiple body areas for this project. Given that users typically use the keyboard for several hours a day, one project assumption is that incorporating vibrations could enhance keyboard interaction and provide rehabilitation integrated into normal daily tasks.

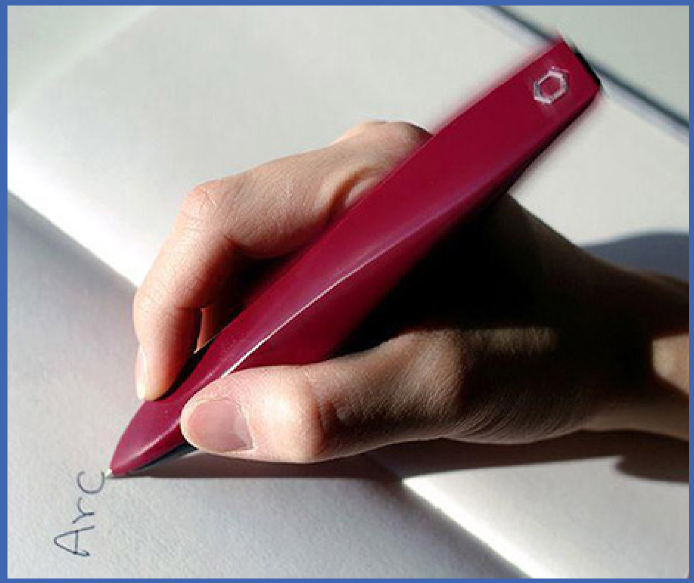


Fig. 2 ARC pen

Fig. 3 Liftware

ARC pen

The ARC pen is the first writing tool specifically designed for those with Parkinson's who suffer from Micrographia. This condition often leads to handwriting that is small, cramped, and uncomfortable, causing many affected individuals to give up writing or drawing entirely. Dopa Solution focuses on addressing higher-level needs to make a significant impact on people's lives. Their approach incorporates high-frequency vibration motors within the ARC pen, which stimulate key hand muscles and reduce the effort required to move the pen across the paper. This innovation helps produce larger and clearer writing. In trials and development involving fourteen individuals with Micrographia, the ARC prototypes showed an overall handwriting improvement of 86% (DOPA-ARC | Lucyjung, n.d.).

Aesthetic features: The pen showcases a bold, ergonomic design with geometric angles and a deep red finish, blending modern aesthetics with functional comfort.

Target Symptom: Micrographia (small, cramped handwriting)

Somatosensory cueing

Concept

Liftware

Liftware offers stabilizing and leveling handles and attachments designed to assist individuals with hand tremors or limited hand and arm mobility in maintaining their dignity, confidence, and independence. This innovative technology includes a spoon that vibrates to counteract tremors, enabling users to eat without spilling food (Liftware, n.d.). However, although Liftware was previously available on the market, as of October 2024, it appears that these products are no longer widely available for purchase.

Aesthetic features: The spoon has a minimalist design with a sleek, white handle and smooth, rounded edges, giving it a unobtrusive appearance.

Target Symptom: Hand tremors

Somatosensory cueing

No longer available on the market

Fig. 4 Albert

Albert

Albert is a walking cane designed to assist individuals with Parkinson's disease and their caregivers, utilizing haptic feedback to address Freezing of Gait (FOG).

Many Parkinson's patients benefit from rhythmic stimuli—whether through touch, sight, or sound—to help overcome FOG and restore motion. Albert's cane incorporates this concept by providing gentle vibrations in the handle to establish a rhythm. Key features include a wall-mounted charging station for safe storage, GPS tracking for caregivers to monitor the user's location, and an emergency beacon to alert medical personnel in case of serious issues (Project: Albert | Miio Studio L, n.d.).

Fig. 5 Color paletter

Aesthetic features: This product features an elevated aesthetic while maintaining a minimalist design. The color palette is refined, with three options—black, white, and light terracotta. The design exhibits high attention to detail, with an elegant and sleek shape .

Target Symptom: Freezing of Gait (FOG)

Somatosensory cueing

Concept

Fig. 6 GaitQ tempo

GaitQ tempo

A subtle vibrational cueing system designed to help individuals with Parkinson's maintain a smoother and more stable gait, gaitQ tempo™ delivers prompts through a discreet device worn on the lower legs, an ideal spot for gait cueing.

gaitQ tempo™ is a non-invasive, portable solution for cueing, enabling users to trigger and adjust the vibration speed with a controller according to their preferences. The device also includes a dock for keeping the system charged and ready for use (gaitQ Tempo | gaitQ Limited, n.d.-b).

Fig. 7 GaitQ tempo components

Aesthetic features: The pod comes in white and red, with the red part mostly concealed within the band. The design is clean and minimalist, featuring soft, rounded forms and a compact size, ideal for a wearable device that aims to remain discreet.

Target Symptom: Gait instability

Somatosensory cueing

Available on the market
though the price is not listed publicly. However, individuals diagnosed with Parkinson's can go through an assessment process to determine suitability for the device.

Fig. 8 CUE1+

CUE1+

The CUE Device employs pulsed cueing and high-frequency focused **vibrotactile stimulation** to relieve symptoms such as slowness, stiffness, rigidity, and freezing of gait. Key benefits include:

Enhanced Movement: Utilizes non-invasive, targeted vibrotactile stimulation and cueing to improve mobility.
Medication Reminders: Incorporates a wearable, discreet, and adjustable system for reminding users to take their medication and for recording adherence.
Symptom Tracking: Enables users to monitor symptoms, track disease progression, and assess quality-of-life measures through the CUE app (Charco Neurotech, 2024).

Fig. 9 Cue+ cases

Aesthetic features: Smooth and compact forms, featuring a neutral color palette, providing an elegant and discreet appearance.

Target Symptom: Slowness, stiffness, rigidity, Freezing of Gait (FOG)

Somatosensory cueing

Available on the market
£795.00 ex. VAT
(CUE1+ FOR PARKINSON'S, n.d.)

Fig. 10 Path Finder

Path Finder

Path Finder is a shoe equipped with **laser projectors** that create lines to initiate walking and prevent 'freezing of gait' (FoG), a frequent symptom of Parkinson's disease.

The laser cues are activated by the pressure detected when the wearer's foot makes contact with the ground. This mechanism allows the standing foot to project a line for the opposite foot, such that the left foot projects a line to guide the right foot forward, and vice versa. The visual cues are thought to trigger movement by capturing the wearer's attention and focusing it on the task of walking (Walk With Path, n.d.).

Fig. 11 Laser cues

Aesthetic features: The bulky design is likely due to the technology integrated into the product, while the black color helps maintain a neutral and discreet appearance, particularly when worn with black shoes.

Target Symptom: Freezing of Gait (FOG)

Visual cueing

Available on the market
€1.175,95
(Path Finder, n.d.)

Fig. 12 Gyenno

Gyenno

This walking aid system assists Parkinson's patients in overcoming freezing of gait, enabling them to walk independently. The device, mounted on the upper part of the shoe, gathers and analyzes data on the wearer's gait. An AI-based algorithm detects irregularities caused by freezing of gait. In response, the device projects a **laser line** onto the floor and/or emits an **acoustic signal** to help the patient resume walking (GYENNO, n.d.).

Fig. 13 Walking aid system

Fig. 14 Vibrating gloves

Vibrating gloves

Researchers at Stanford Medicine have created gloves that greatly enhance the lives of Parkinson's Disease patients. These gloves employ fingertip vibrations to reprogram the brain and ease symptoms.

A study revealed that wearing the gloves lessened tremors, stiffness, abnormal walking, slow movements, and balance problems. Additionally, patients noted improvements in mood swings, behavioral changes, depression, and loss of smell and taste, despite these not being the primary focus of the study (Hannon, 2024).

Fig. 15 Cue2Walk

Cue2Walk

The Cue2walk helps prevent and manage mobility challenges associated with Parkinson's by delivering personalized cues through vibrations and/or beep signals, providing both tactile and auditory feedback.
These cues encourage intentional movement, helping users overcome gait disturbances more efficiently. Discreetly worn on the leg under clothing, the device is made with soft, comfortable fabric, allowing it to be worn throughout the day. It is adaptable to a range of daily activities, including standing up, making sharp turns, or stepping over obstacles like thresholds. Fully customizable, it ensures the necessary support is provided exactly when needed, making everyday tasks smoother and more manageable (Product – Cue2walk, n.d.).

Aesthetic features: The white appearance helps maintain a clean and minimalist design, while the gray bands offer a practical compromise, keeping the look neutral and likely resistant to showing dirt.

Aesthetic features: The appearance of this product is entirely black, bulky, and somewhat intrusive on the user's hands, but it is still in the development phase.

Aesthetic features: The design closely resembles the GaitQ Tempo (fig. X) keeping a clean, minimalist aesthetic with soft contours and a neutral band. However, this pod being entirely white is even more neutral.

Target Symptom: Freezing of Gait (FOG)

Target Symptom: Tremors, stiffness, abnormal gait, slow movements, and balance issues.

Target Symptom: Tremors, stiffness, abnormal gait, slow movements, and balance issues.

Visual and auditory cueing

Available on the market
£1,078.80 inc VAT
(Gyenno SkyWalk Bold Parkinsons Gait Aid System, n.d.)

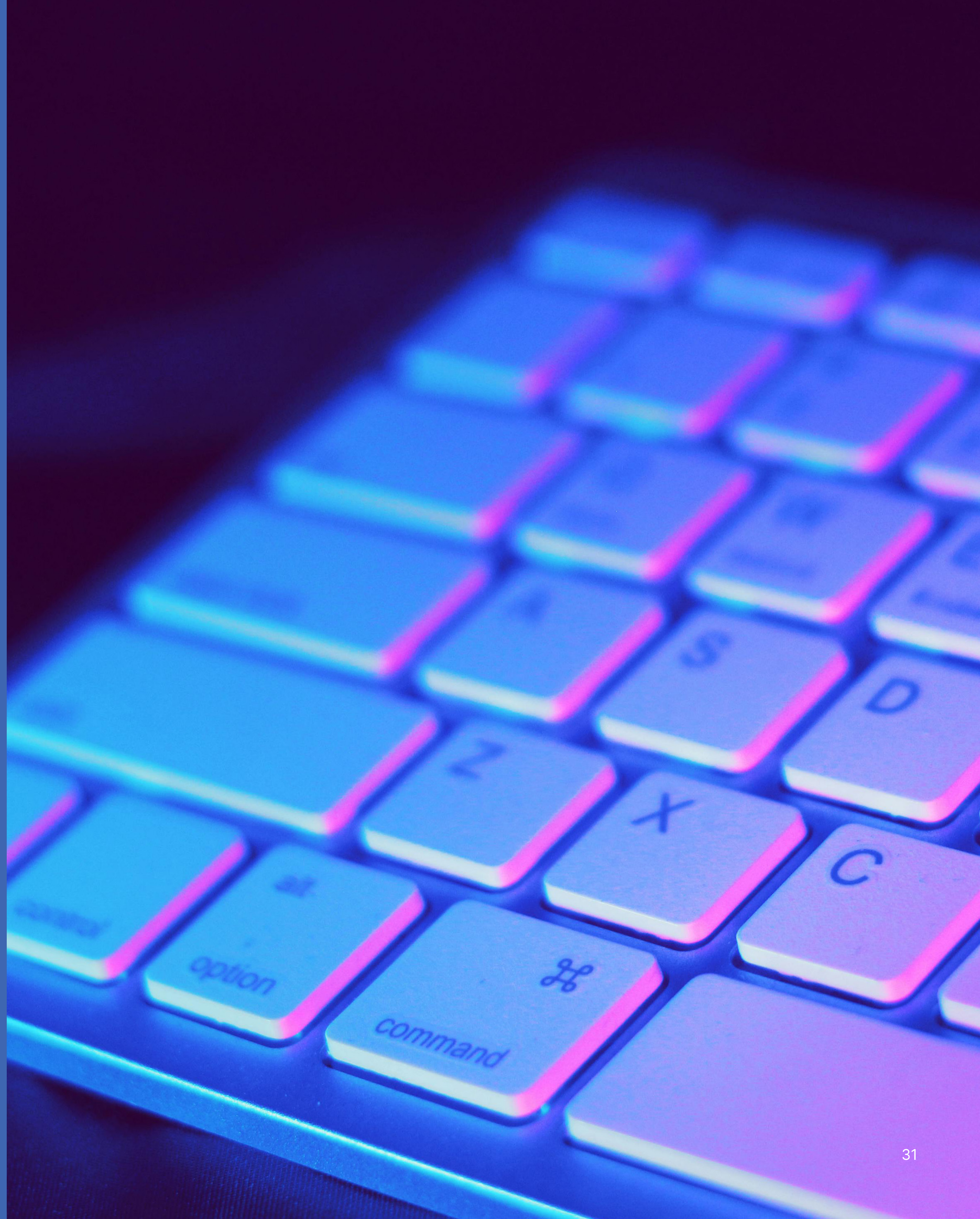
Somatosensory cueing

Concept

Somatosensory and auditory cueing

Available on the market
€ 795,00
(Product – Cue2walk, n.d.)

5. Computer keyboard



5.1 Keyboard layout

This section delves into the study of computer keyboards to examine available products and the application of cueing techniques in this area. A computer keyboard serves as an input device, drawing inspiration from the typewriter, with its buttons or keys functioning as mechanical levers or electronic switches. The primary keyboard layouts worldwide include qwerty, azerty, dvorak, and qwertz, named after the sequence of the first six keys in the top row of letters. The qwerty layout is predominant in the Americas and some parts of Europe, qwertz is utilized in German-speaking regions, and azerty is common in France and Belgium.
The original configurations, such as qwerty, were developed to prevent typewriter jams rather than to enhance linguistic or ergonomic efficiency. Although alternative designs like the dvorak layout have been introduced, the qwerty layout remains the most widely used. Since this graduation project is being conducted in the Netherlands, the qwerty keyboard (Fig. 16) has been selected for this project as it is the most commonly used layout in the country (Wikipedia contributors, 2024).

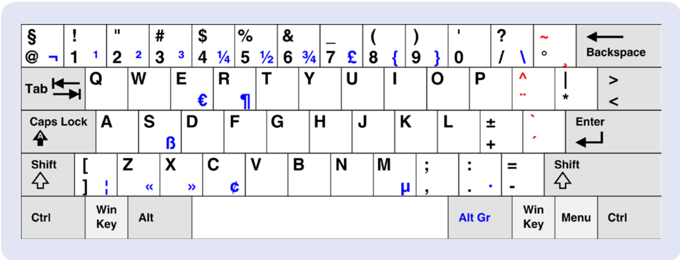


Fig. 16 Dutch keyboard layout

5.2 Keyboars' types

When discussing keyboards, it is essential to understand the various types available. The main keyboard switch types include membrane (or rubber dome), scissor, and mechanical switches. **Membrane keyboards**, which use rubber dome switches, are very common. They work by pressing a rubber dome that contacts the PCB (Printed Circuit Board) to register a keypress. These keyboards lack tactile feedback and require full keypresses, which can lead to finger fatigue and potentially carpal tunnel syndrome over time. **Scissor switches**, often found in laptops, are a variation of rubber dome switches. They use a crisscross mechanism for stability and provide slight tactile feedback. **Mechanical keyboards** are renowned for their durability and use metal coil springs for key return. Unlike membrane switches, mechanical switches do not require full keypresses to register. Mechanical switches (Fig. 17) are categorized into linear, tactile, and clicky variants:
1. Linear switches: Smooth with no tactile bump or click, preferred by gamers for fast and seamless keypresses.
2. Tactile switches: Provide a tactile bump, offering feedback without a loud click.
3. Clicky switches: Feature both a tactile bump and an audible click, favored by typists for clear feedback.

Additionally, mechanical keyboards can feature either soldered or hot-swappable switches, allowing for easy customization or replacement (Hebert, 2020). Because of its qualities, the mechanical keyboard with clicky switches has been selected for this project.

Fig. 17 Mechanical switches

5.3 Ortholinear vs Staggered

Additionally, keyboards vary in how their keys are arranged, with two primary types of layouts: staggered and ortholinear. The staggered layout features keys arranged in a diagonal pattern, while ortholinear keyboards have keys aligned in straight vertical and horizontal lines, forming a uniform grid (Fig. 18) (Fairy, 2020). The staggered layout originated from the design of the original QWERTY typewriter, which needed staggered keys to maintain equal spacing and prevent the mechanical arms from colliding. Despite technological advancements, the staggered layout persists due to its historical origins and widespread use, rather than for ergonomic reasons. Some people believe that ortholinear layouts can help alleviate symptoms of repetitive strain injuries, although there is no research currently available to support this claim (Staggering - Deskthority Wiki, n.d.). Nevertheless, potential benefits of using ortholinear keyboards have been suggested:

Reduced Finger Movement: This design aims to shorten the distance your fingers need to travel, enhancing typing efficiency by minimizing the side-to-side motion required to reach each key. It aligns more naturally with the vertical movement of your fingers, which may help reduce finger strain and fatigue (Liu, 2024).

Compact Design: Ortholinear keyboards are often smaller (Liu, 2024), making them a suitable choice for people with Parkinson's disease, as they might help limit the range of movement required.

In conclusion, while it is not possible to definitively state that the ortholinear layout is more ergonomic than the staggered layout, the potential benefits of the ortholinear design make it the preferred choice for this project, considering the needs of people with PD.

Fig. 18 Staggered and ortholinear keyboard

Fig. 19 Backlit keyboard, Visual cueing

5.4 Cueing techniques applied to keyboards

As previously introduced, cueing techniques are external stimuli that help the user focus on a particular task. It is fortunate that various keyboards on the market already incorporate multiple feedback mechanisms to enhance the user experience, particularly in gaming. Exploring the available market options is essential to understand what could be applied to this project.
Mechanical keyboards are prized by gamers for their exceptional performance and distinct tactile response. These keyboards are sought after for their ability to deliver high performance and a unique physical feel. Each key press produces a satisfying click or bump, enhancing control and accuracy during gameplay. The tactile sensation and **audible clicks** deepen gaming immersion and precision, providing effective **auditory cues** (MeeTion, 2024). Moreover, keyboards equipped with **piezo buzzers** add auditory feedback, where each keystroke can generate a sound (Equals 60 | Boardsource, n.d.).
Customizable **backlighting** options enable gamers to select from a variety of colors or create personalized lighting profiles. This feature helps in identifying keys in low-light conditions, thereby improving gaming performance and experience through **visual cues** (Fig. 19) (MeeTion, 2024).
Furthermore, touchscreen keyboards available on the market offer **somatosensory cues**, including **buzzer** responses when keys are pressed. An overview of these types of feedback can be found in Appendix C.
These technologies, already accessible on the market, if adapted to our requirements, could enhance the typing efficiency of individuals with Parkinson's.

5.5 Keyboards designed for Parkinson's Disease

There are only a few keyboards on the market designed for people with motor difficulties, and even fewer are specifically designed for people with Parkinson's disease.

Fig. 20 Keyboard with bigger keys

The QueenKey keyboard is the same size as a standard keyboard but features larger keys. This design makes the keys easier to find, press, and read. QueenKey is beneficial for individuals with visual or motor impairments due to the larger keys and vivid colors (QueenKey, n.d.)

Fig. 21 Programmable keyboard

Programmable keyboard that can be configured to meet the specific needs of any user, making it a quick access keypad for PCs. It can replicate mouse and keyboard commands, activate macros, shortcuts, select tools, and open files or directories. It is ideal for users who primarily operate their computer via the keyboard and need to reduce keystrokes (Compact keyboard for quick PC operation, n.d.)

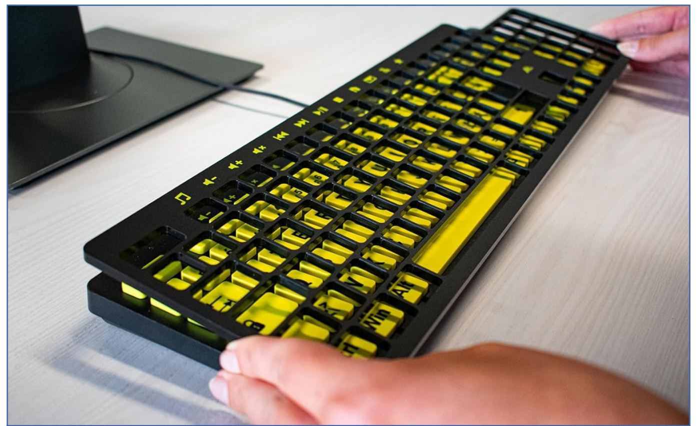


Fig. 22 Keyguards

Keyguards are molded plastic overlays with holes that isolate each key. This is suitable for anyone who has difficulty with fine hand control and wants to limit the unintentional pressing of multiple keys (Keyguard, n.d.)

Fig. 23 Morphological chart

5.6 Morphological chart

To initiate the ideation process, a morphological chart (Fig. 23) was used, which was divided into several categories: dimensions, shape, key design (shape and thickness), and additional features/accessories.
Regarding dimensions, keyboards can vary from very compact models with only essential keys to larger versions, such as full-sized 100% keyboards that include a number pad. Since people with Parkinson's disease have a reduced range of motion, the keyboard should be compact yet still offer all necessary functions. I chose a 65% keyboard layout for this reason.
In terms of shape, keyboards differ in their ergonomic design. Notable models include mechanical keyboards with adjustable angles through a hinge mechanism, allowing users to control the keyboard's position, and split keyboards with two unattached halves. These designs help reduce strain on the back and arms, promote a more natural posture, and enhance comfort during extended use.
When considering the keys, there are various shapes and thicknesses available. Very thin keys are ideal for laptops but lack ergonomic support. Thicker keys generally offer better ergonomics. However, my preference is for keys equipped with a keyguard, which are especially useful for users with tremors.
Finally, I explored various additional features and accessories. These include backlighting, silicone dampeners to reduce key noise, stickers to customize and differentiate specific keys, palm rests, adjustable legs to raise the keyboard to a user-defined height, and dust covers. Palm rests were selected as valuable accessories for improving keyboard ergonomics, along with an adjustable back stand.
In conclusion, the morphological chart provided valuable insights to ensure that no potential features were overlooked in the final design.

5.7 Design goal and requirements

To guide the design process, a design goal and a list of design requirements was established based on the findings from the research phase. The requirements are categorized into demands (essential criteria the product must meet) and wishes (desirable features). Moreover, findings are provided as points supports for each requirement (Fig. 24).

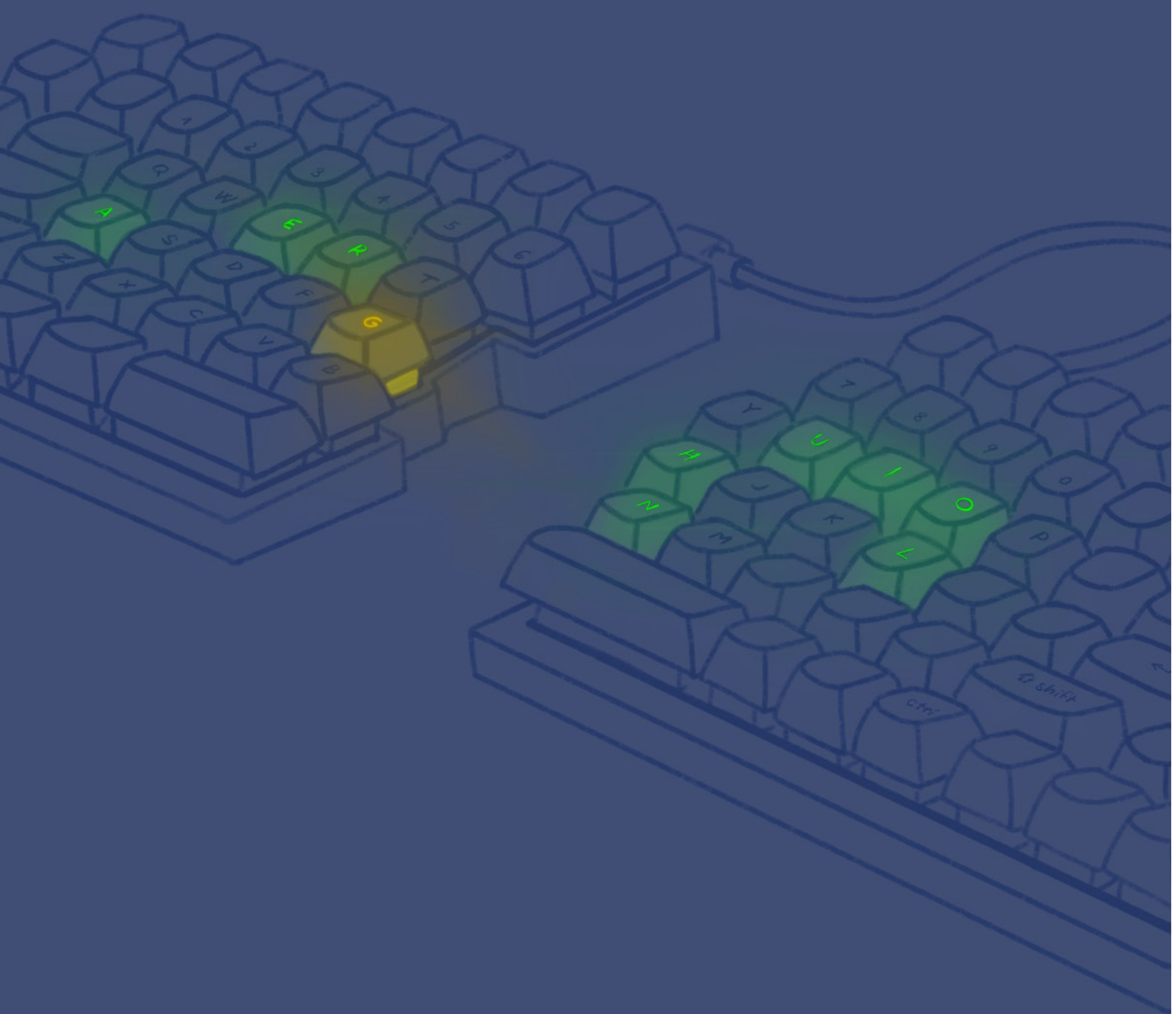
Design goal:

> "**Enhance computer keyboard interaction for people with Parkinson's disease, specifically targeting the symptom of bradykinesia.** By doing so, the project aims to **improve their quality of life and empower individuals, helping to reduce the frustration** they currently experience when using a keyboard."

	Findings	Requirements
1	People with PD experience bradykinesia, which makes keyboard use challenging due to reduced movement, increased errors, and freezing (The Many Faces of Bradykinesia in Parkinson's Disease, 2020), leading to frustration and a decrease in quality of life. Cueing techniques (external stimuli which provide information to facilitate movement initiation and continuation) can be beneficial in addressing PD symptoms (Sweeney et al., 2019).	The keyboard *must* reduce the influence of bradykinesia in computer interaction providing visual/auditory/ somatosensory cue empowering individuals and reducing their feeling of frustration.
2	A study found that 86.5% of Parkinson's patients had asymmetry, with symptoms often starting on the dominant side, which was linked to a higher likelihood of bradykinesia (Barrett et al., 2010).	The keyboard *must* be designed to be fully operable with one hand if necessary.
3	Bradykinesia causes a progressive reduction in the amplitude of repetitive actions (Berardelli, 2001).	The keyboard *must* be compact (size 65%, 68- keys).
4	Bradykinesia causes a progressive reduction in the amplitude of repetitive actions (Berardelli, 2001).	The keyboard *must* have adjustable amplitude allowing people to maintain a natural and unforced posture.
5	Auditory cueing uses rhythmic sounds to synchronize movements and improve gait in those with motor difficulties (Sweeney et al., 2019).	The keyboard *must* have clicky switches which provide a tactile bump and an audible click.
6	Around 70-90% of individuals with PD will experience tremors at some stage in their lives (Parkinson's fundation, n.d.). Tremors, combined with bradykinesia, negatively impact keyboard interaction.	The keyboard *must* be designed to accommodate users with tremors.
7	Different individuals experience varying symptoms and needs (Andrejack & Mathur, 2020).	The keyboard *must* be be modular and customizable.
8	Visual cues, like contrasting colors and clear markers, can help people with Parkinson's navigate safely, improve movement, and reduce freezing (DIY: Using Visual Cues to Live Better With PD, 2019). Thus, they may assist in easier key identification.	The keyboard *should* have keys of different colors.

Fig. 24 Findings and requirements

6. Conceptualization



6.1 Approach

This section delves into the conceptualization phase, building on the research from the previous chapter by integrating the knowledge gained to propose potential solutions. Taking a holistic approach, which considers the system as a whole and its interconnected components, the project categorizes various concepts based on different cueing techniques. The concepts presented focus on implementing these techniques: the first two incorporate somatosensory cues, the third utilizes auditory cues, and the last two employ visual cues.
These concepts should not be viewed as standalone ideas but as distinct features that can be integrated into the final design. Prototypes were developed to test their functionality. Consequently, this chapter explains each concept by addressing the related feature and the prototype designed to test all, or specific aspects, of these features.

6.2 Prototyping

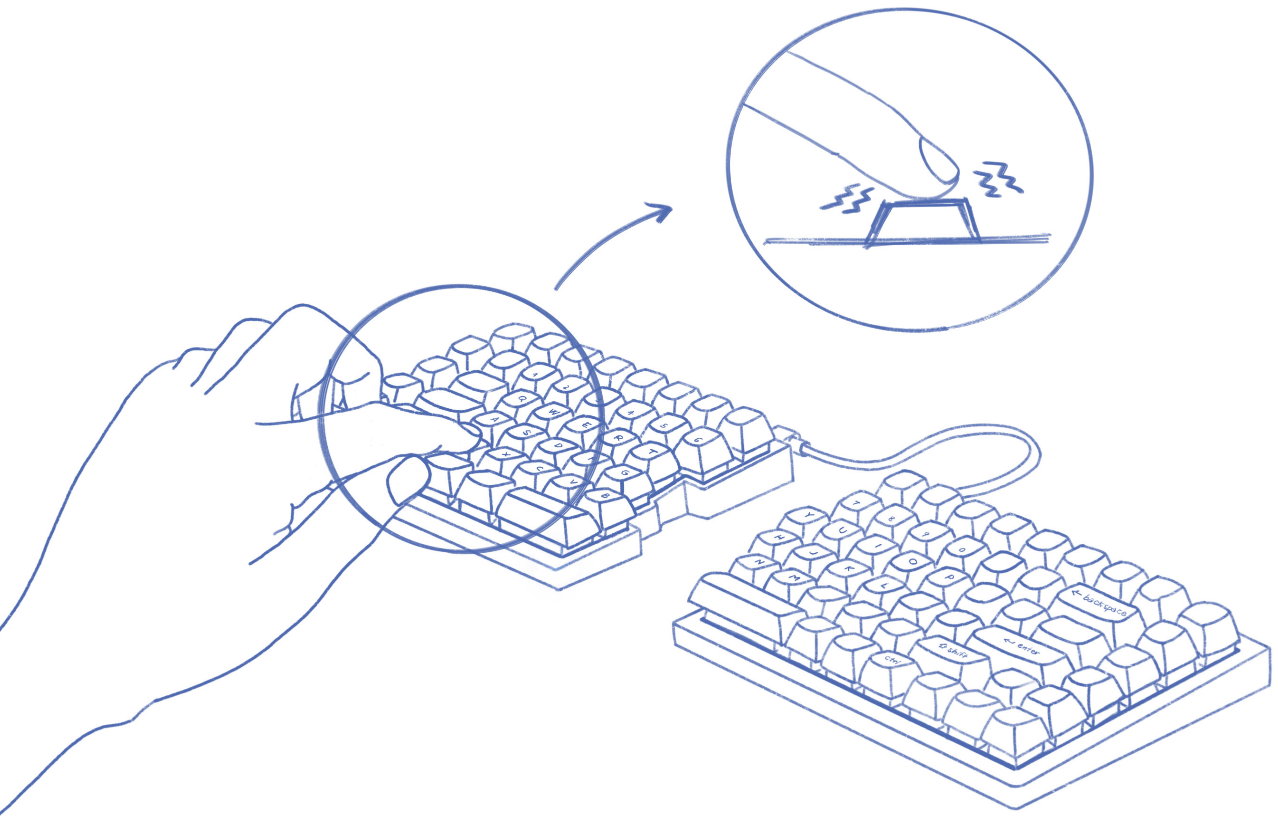
The prototypes feature a simplified design, opting for a 12-key layout instead of a full keyboard to enhance practicality and reduce the complexity of the required electronics. Each prototype consists of mechanical switches arranged on a 12-key pad, enclosed in a custom 3D-printed case (Fig. 25). These switches are programmed using an Arduino Micro board, offering a flexible and efficient platform for testing key functionalities. This method facilitates rapid prototyping and iteration.

Fig. 25 12-key Pad

VIBRATING KEYS

6.3 Concept 1

The first concept demonstrates the implementation of haptic feedback (somatosensory cue). In this design, users receive tactile vibrations directly on their **fingertips** when interacting with the keyboard. This haptic feedback aims to provide sensory cues that can help users with Parkinson's improve their typing accuracy and maintain a steady rhythm while typing. By delivering gentle vibrations upon each keystroke, the system enhances the user's awareness of key presses, potentially reducing typing errors and offering additional sensory input to compensate for any lack of tactile sensation. This concept requires the user to perform an action (pressing a specific key) to activate the haptic feedback, as illustrated in figure 26. If this action is not performed, the feedback will not be triggered.



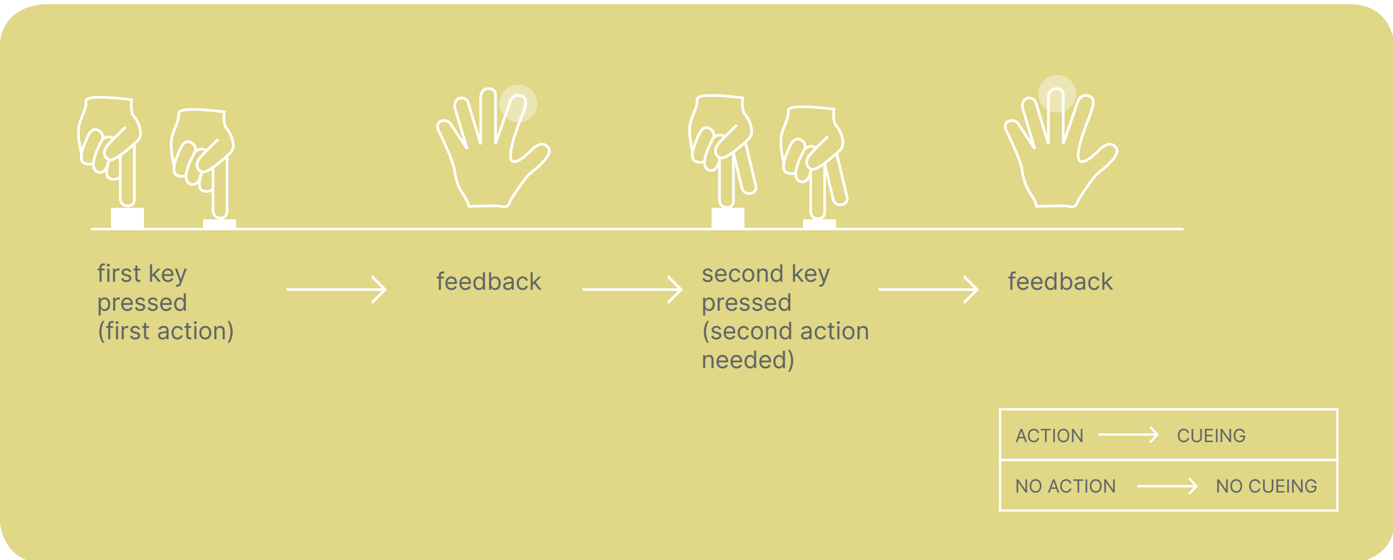


Fig. 26 Action-Feedback Diagram

Fig. 27 Prototype Concept 1

FEATURES

Fig. 28 Vibrating keys

1. Vibrating keys
Each time a key is pressed, the switch vibrates. In the final design, users will have the option to adjust the vibration intensity to suit their preferences.

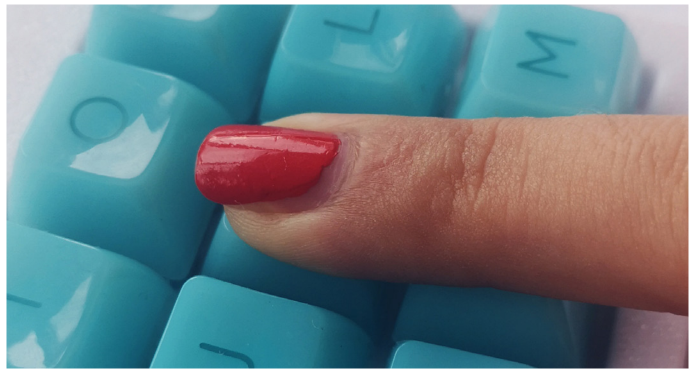


Fig. 29 Key Press Feedback for Stuck Finger

2. Stuck finger
If a user's finger remains stuck on a key, the vibration intensity will increase to provide stronger physical feedback, prompting the user to lift their finger. To prevent repeated characters, the keyboard will only register a single keystroke when continuous pressure is applied.

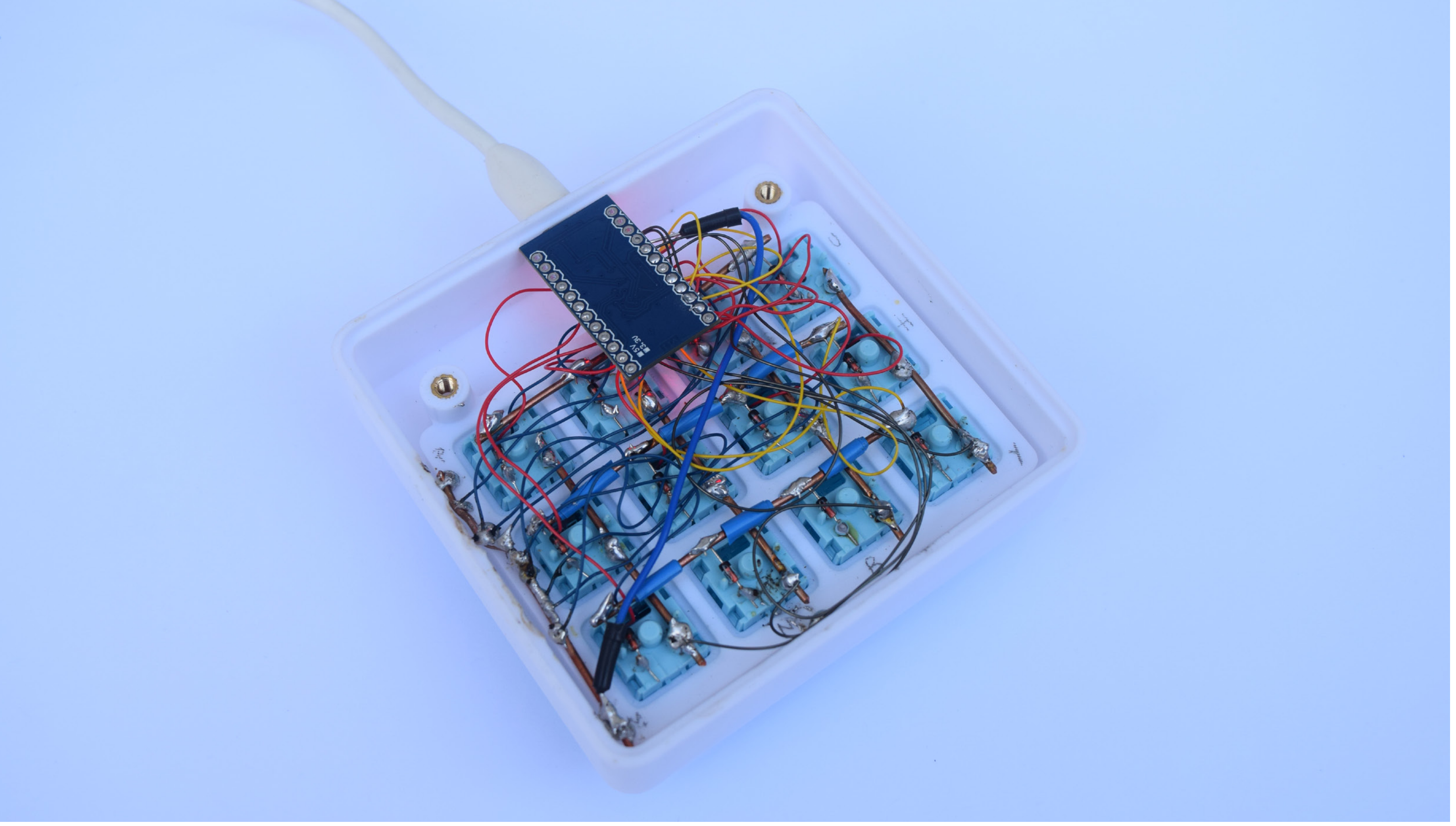


Fig. 30 Hardware

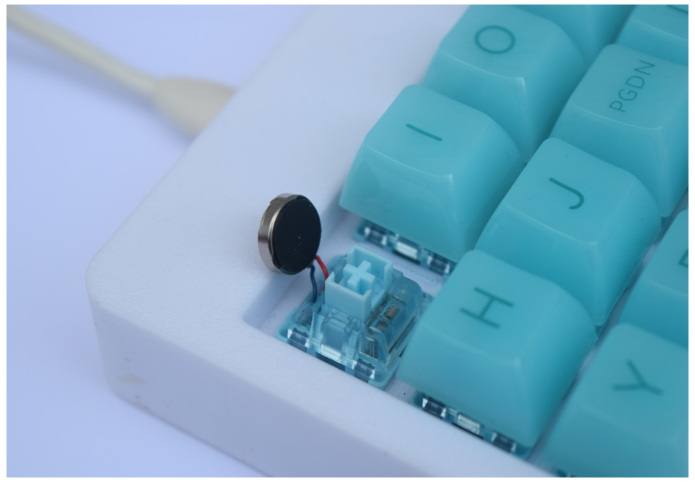


Fig. 31 Vibrating motor

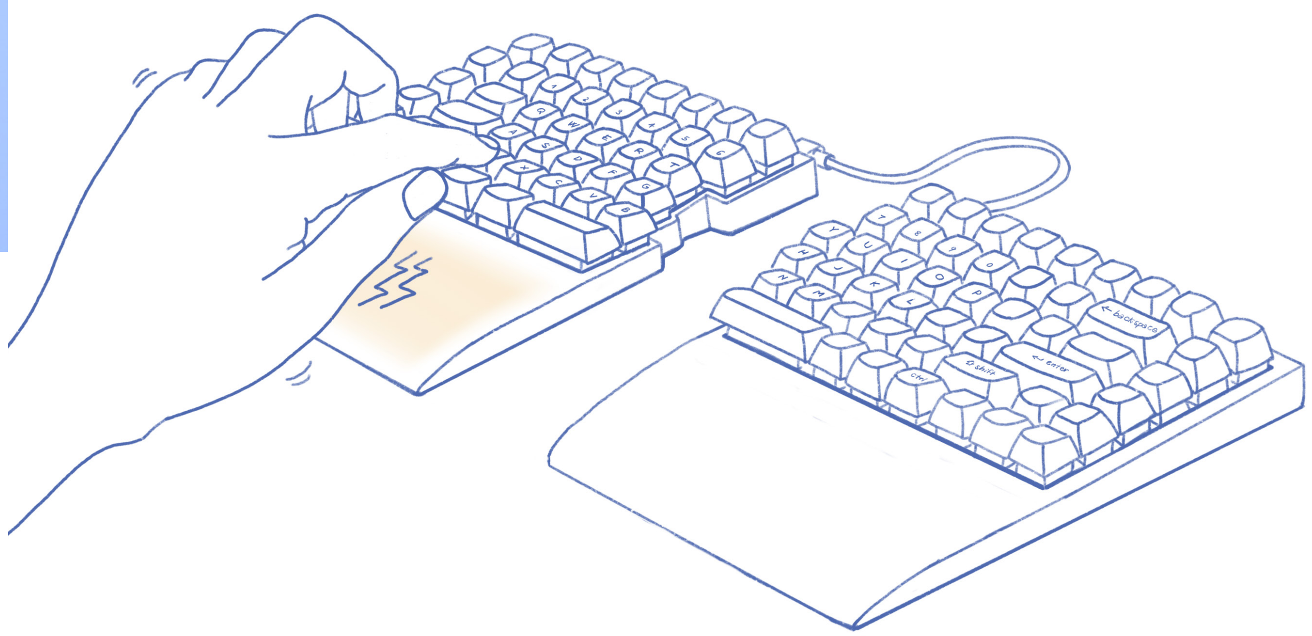
PROTOTYPE

This prototype is a hand-wired keyboard matrix that includes vibrating motors beneath the keycaps. (Further details can be found in the appendix E).

VIBRATING PALM REST

6.4 Concept 2

The second concept implements haptic feedback in the keyboard's palm rest. Each time a key is pressed, the palm rest vibrates, providing feedback to the user through their **palm**. This design allows users to receive cues without needing to wear an external device, utilizing an element that is already part of the keyboard. In case of bradykinesia, if the user takes too long to initiate an action, the keyboard detects the delay and sends a vibration to the palm rest. This prompt helps the user continue typing by providing a tactile trigger, as illustrated in figure 32. Since each person may experience a different delay, the user should be able to select after how many seconds they prefer to receive this trigger.



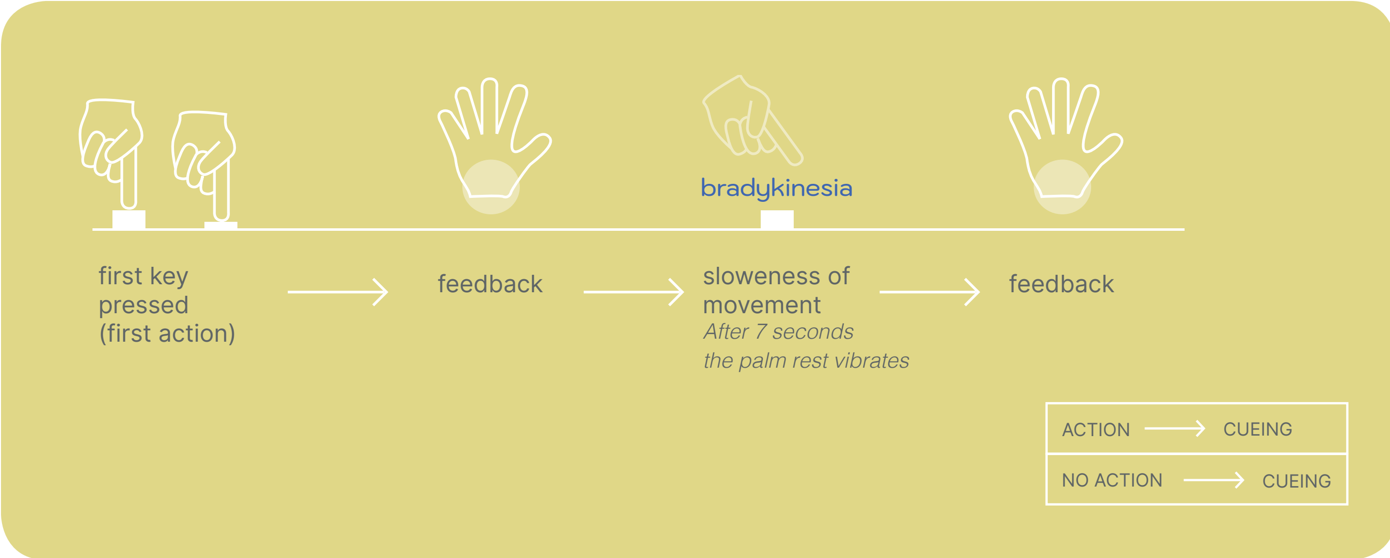


Fig. 32 Action-Feedback Diagram

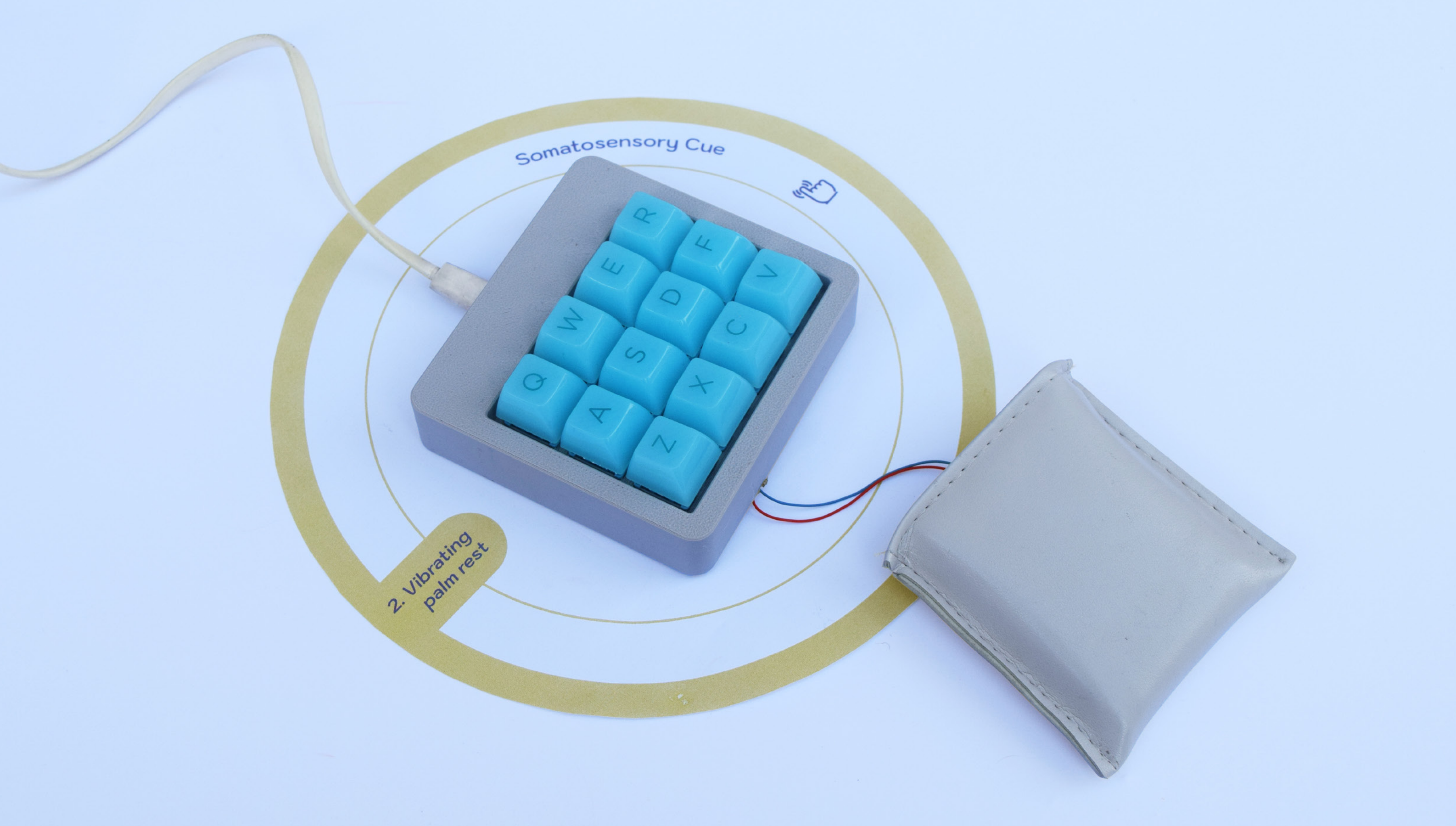


Fig. 33 Prototype Concept 2

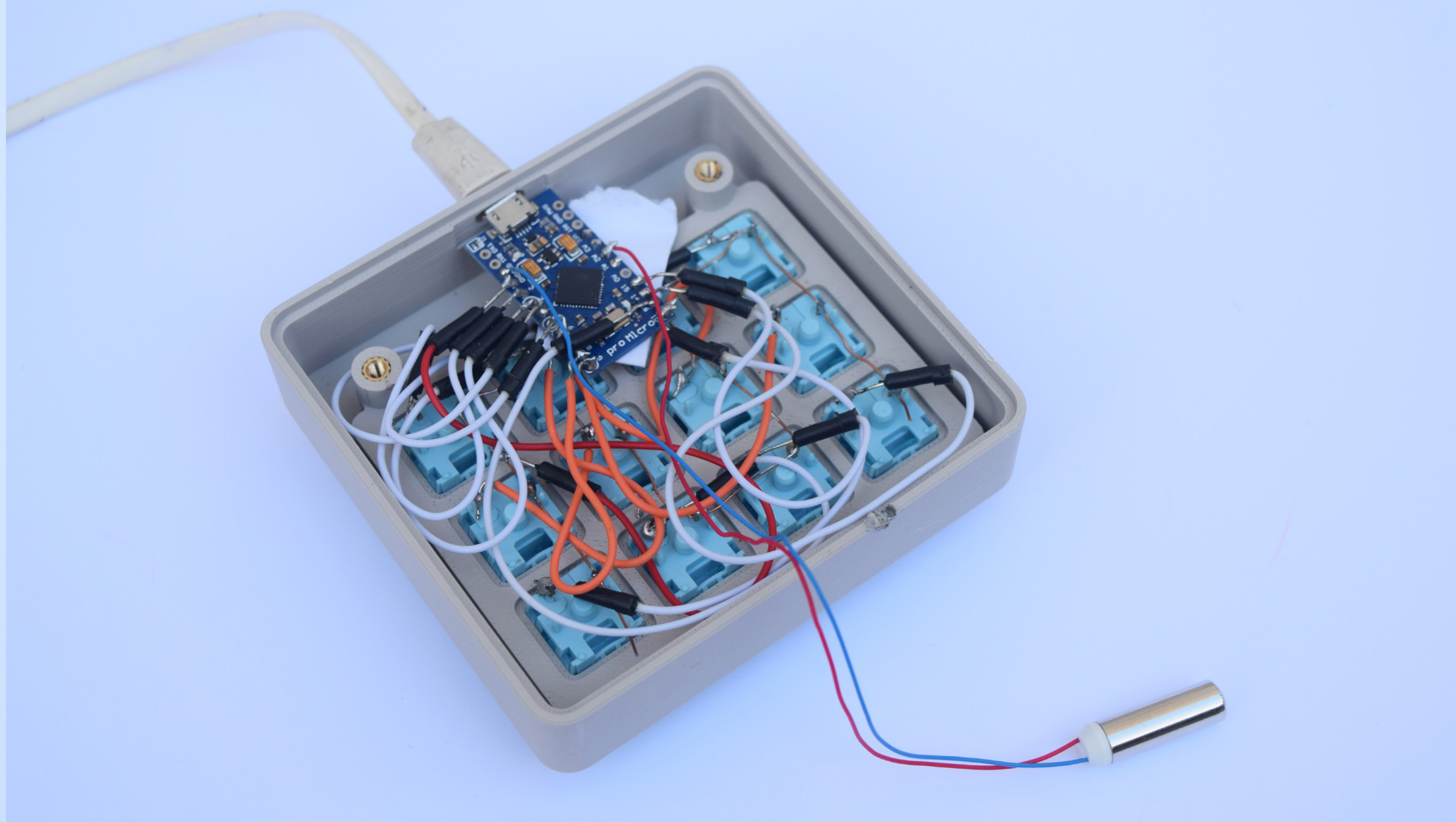


Fig. 37 Hardware

FEATURES

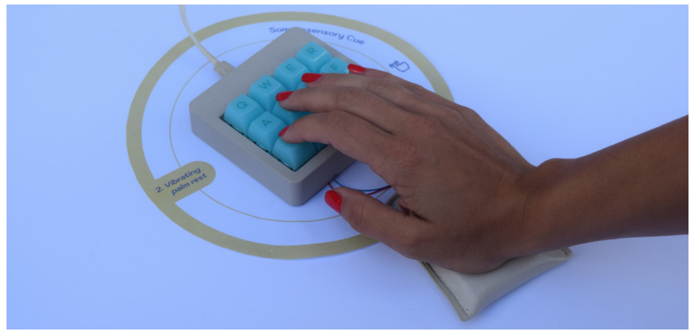


Fig. 34 Vibrating palm rest

1. Vibrating palm rest
Each time a key is pressed, the palm rest vibrates. In the final design, users will have the option to adjust the vibration intensity to suit their preferences.

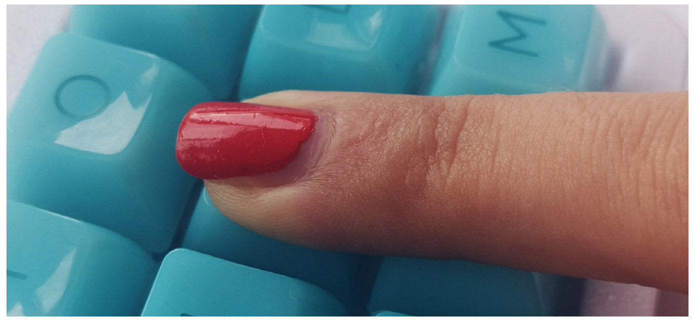


Fig. 35 Stuck Finger

2. Stuck finger
If a user's finger gets stuck on a key, the palm rest will vibrate multiple times to provide physical feedback, encouraging the person to lift their finger. To avoid repeated letters, the keyboard will only type one letter when constant pressure is applied.

Fig. 36 Freezing prevention

3. Freezing Prevention
If the user does not press any keys for seven seconds, the palm rest vibrates to prompt them to continue typing. In the final design, users will have the option to adjust the time delay to match their preferences, allowing them to set the number of seconds before the vibration is triggered.

Fig. 38 Vibrating motor

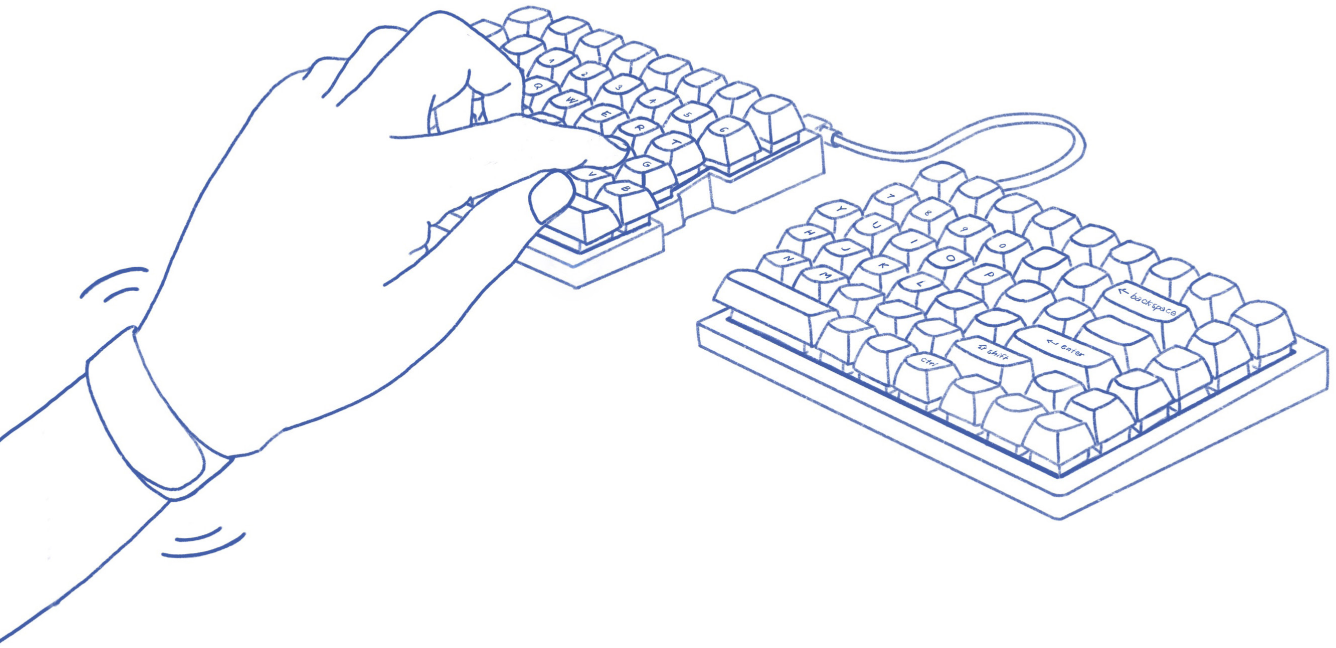
PROTOTYPE

This prototype is a hand-wired keyboard featuring a vibrating motor embedded in a soft palm rest (Further details can be found in the appendix E).

VIBRATING CUFF

6.5 Concept 3

The third concept incorporates haptic feedback in a cuff that is wirelessly connected to the keyboard. Each time a key is pressed, the cuff vibrates, providing feedback to the user through their wrist. This design allows users to be more free with their movements while using the keyboard. In cases of bradykinesia (slowness of movement), if the user takes too long to initiate an action, the keyboard detects the delay and sends a vibration to the cuff. This prompt helps the user continue typing by providing a tactile trigger, as illustrated in figure 39. Since each person may experience a different delay, the user should be able to select after how many seconds they prefer to receive this trigger.



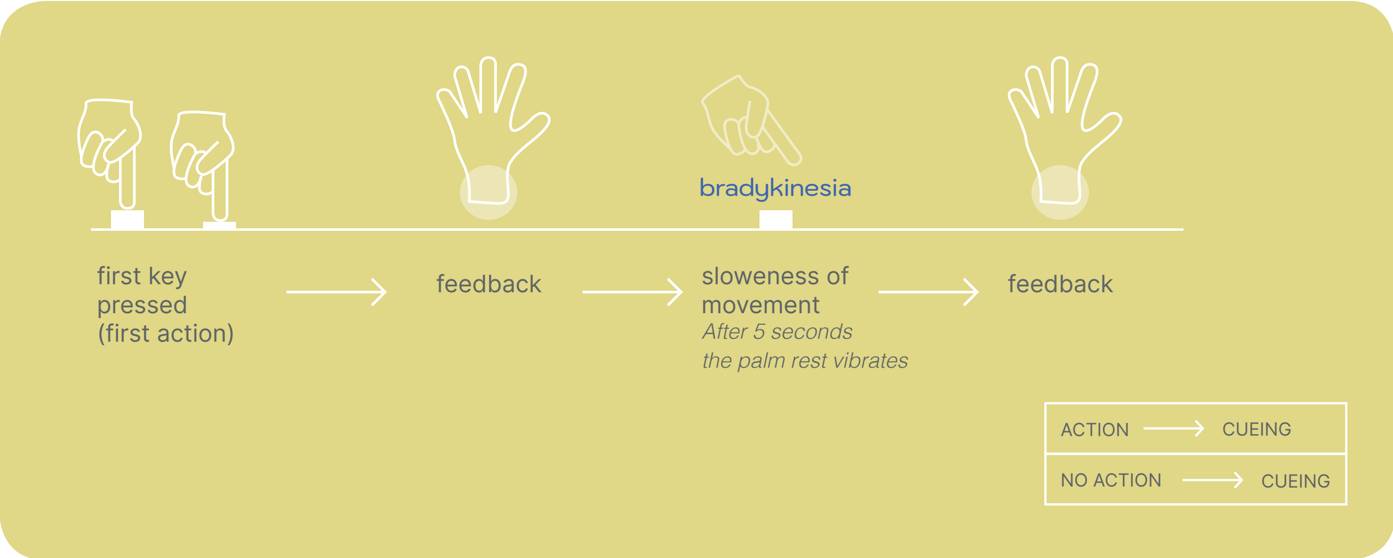


Fig. 39 Action-Feedback Diagram

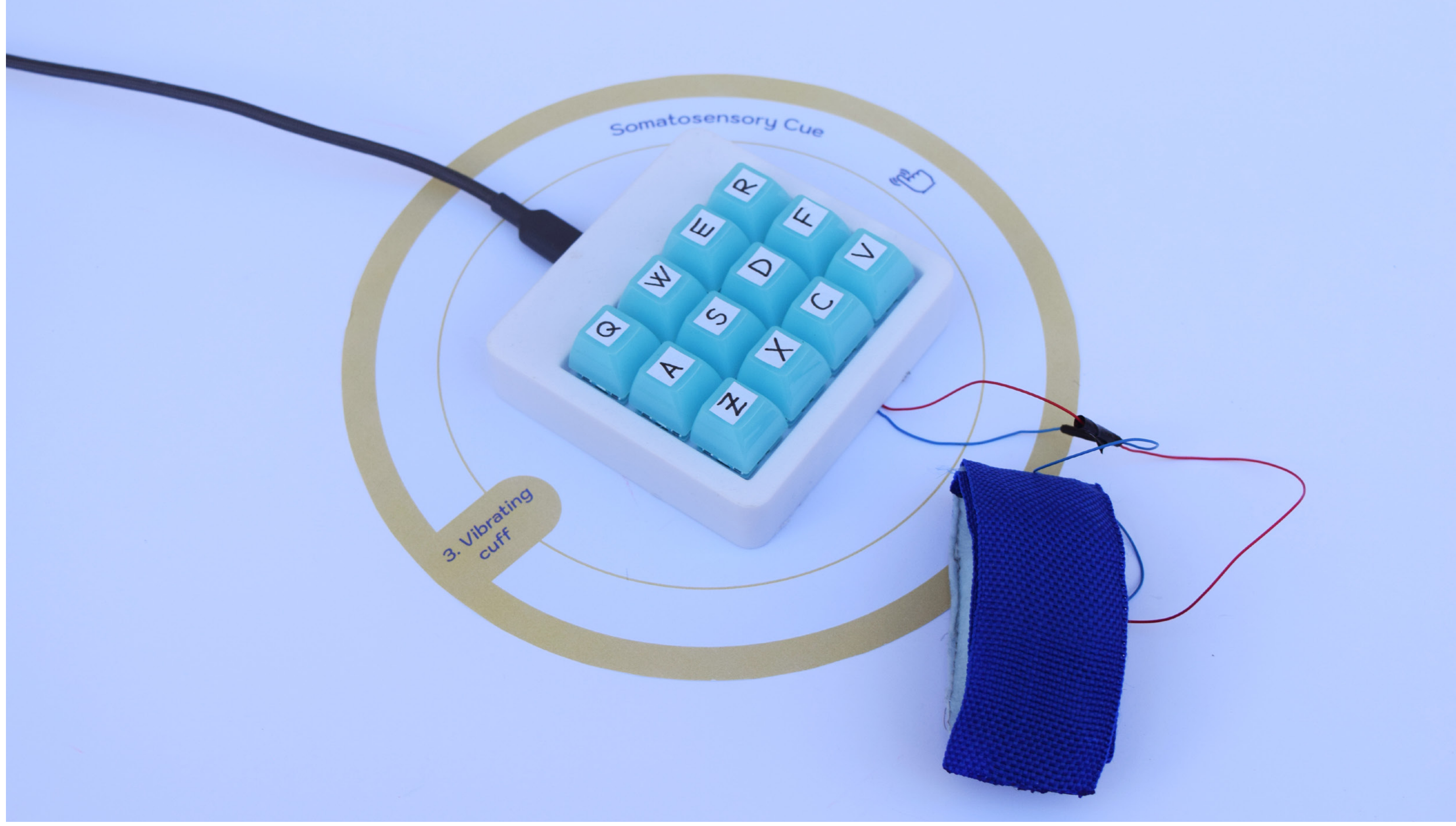


Fig. 40 Prototype Concept 3

FEATURES

Fig. 41 Vibrating palm rest

1. Vibrating cuff
Every time a key is pressed, the cuff vibrates. In the final design, users will have the option to adjust the vibration intensity to suit their preferences.

Fig. 42 Stuck Finger

2. Stuck finger
If a user's finger gets stuck on a key, the cuff will vibrate to provide physical feedback, encouraging the person to lift their finger. To avoid repeated letters, the keyboard will only type one letter when constant pressure is applied.

Fig. 43 Freezing prevention

3. Freezing Prevention
If the user does not press any keys for five seconds, the cuff vibrates to prompt the user to continue typing. In the final design, the user will be able to set the time delay for this function according to their preferences.

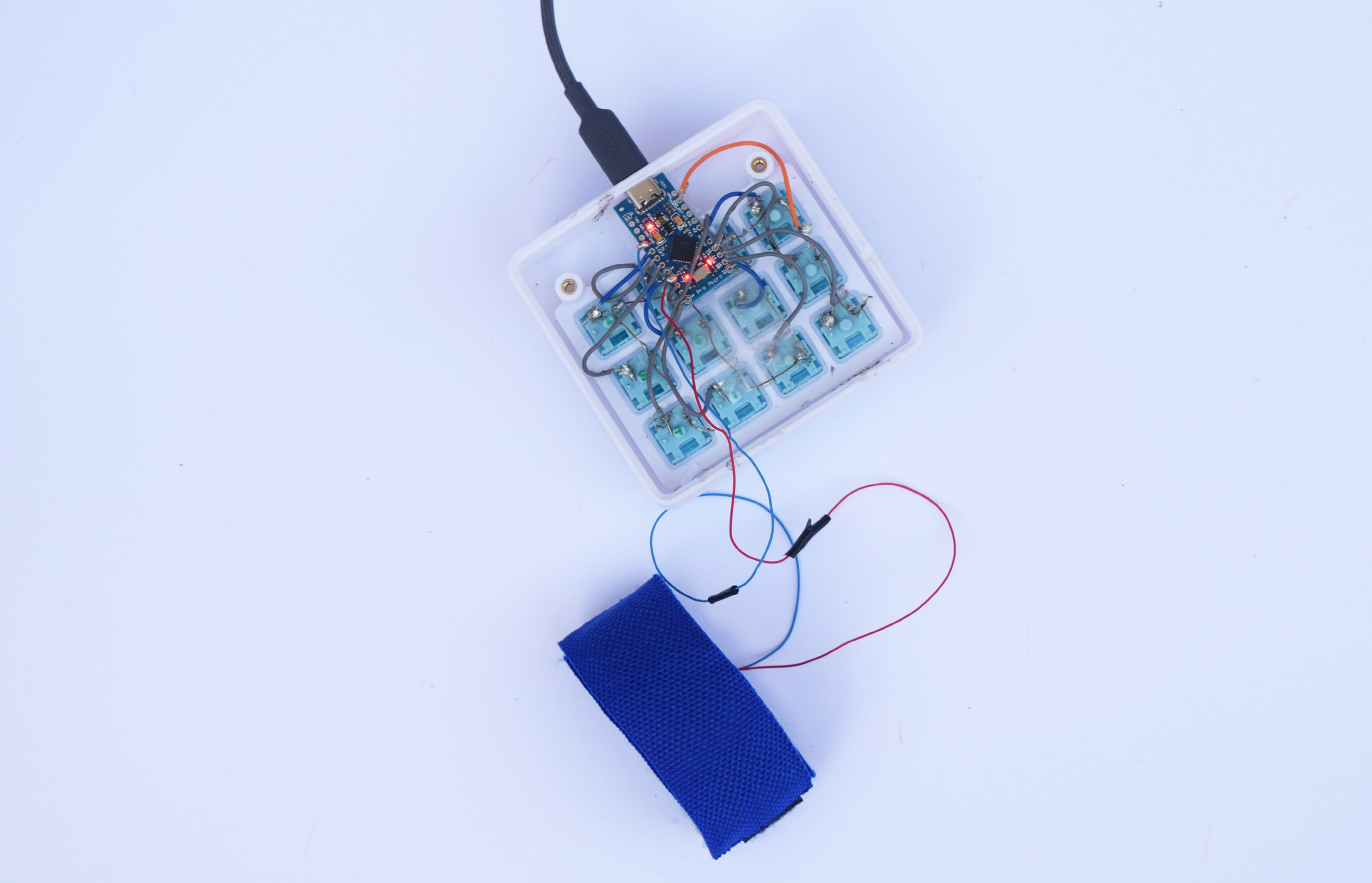


Fig. 44 Hardware

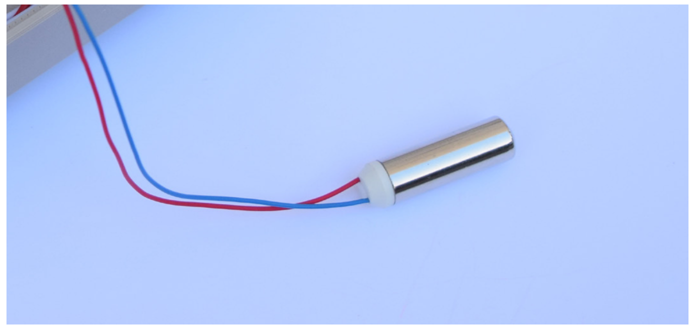


Fig. 45 Vibrating motor

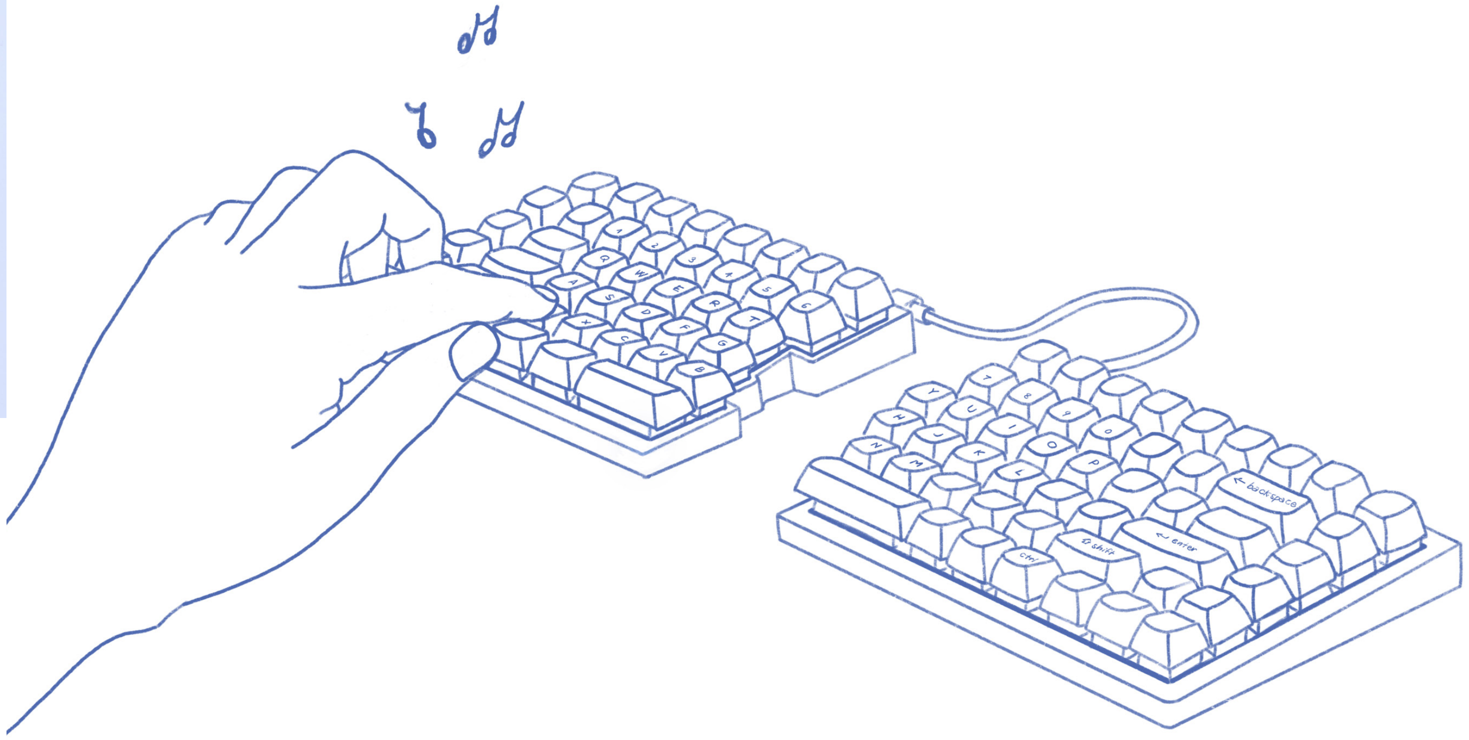
PROTOTYPE

This prototype is a hand-wired keyboard featuring a vibrating motor, which is integrated into a soft cuff. (Further details can be found in the appendix E).

RHYTHMIC KEYS

6.6 Concept 4

The fourth concept incorporates auditory cues. Each time a key is pressed, the keyboard plays a sound. Instead of assigning a specific sound to each key, a different sound is randomly selected from a set of predefined frequencies with each keypress, ensuring it is always slightly different. Letters have distinct sounds compared to symbols, making them easily distinguishable. In cases of bradykinesia, where the user may take too long to initiate an action, the keyboard detects the delay and emits a series of sounds to help the user regain their rhythm. This sound functions similarly to a metronome, a tool commonly used in Parkinson's therapy to help maintain a steady rhythm. This auditory prompt assists the user in continuing to type by providing rhythmic cues, as shown in figure 46. Since the delay between actions can vary from person to person, the final design must allow users to customize the trigger time and adjust the volume to suit their individual needs.



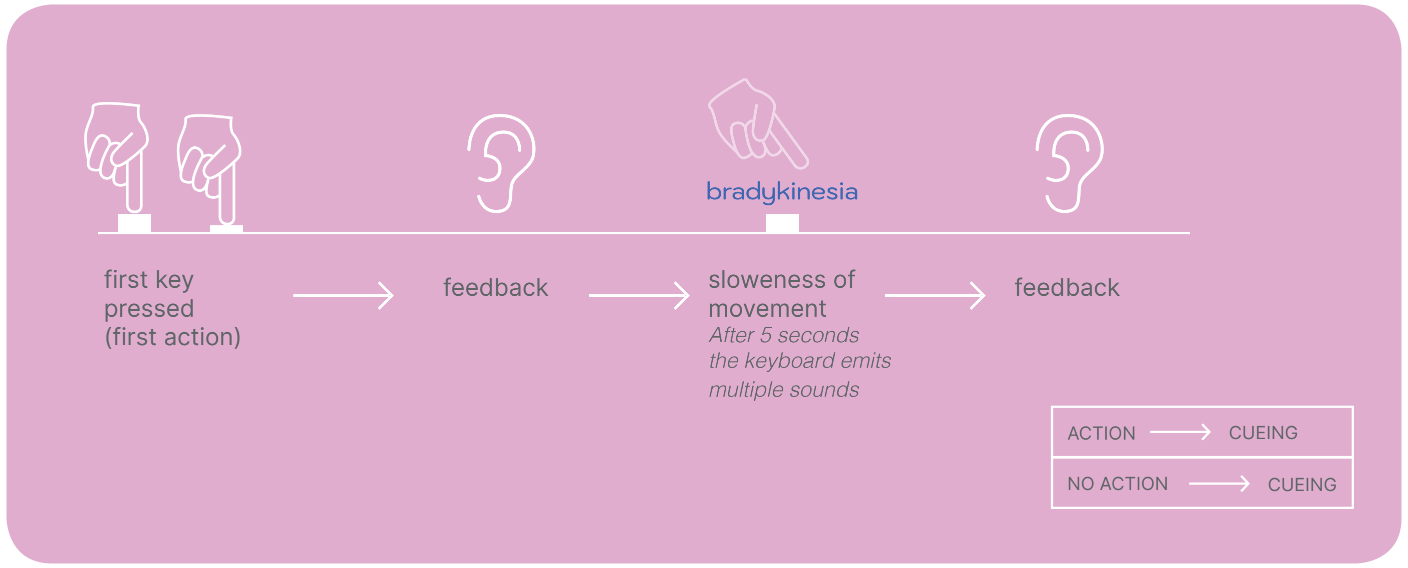


Fig. 46 Action-Feedback Diagram

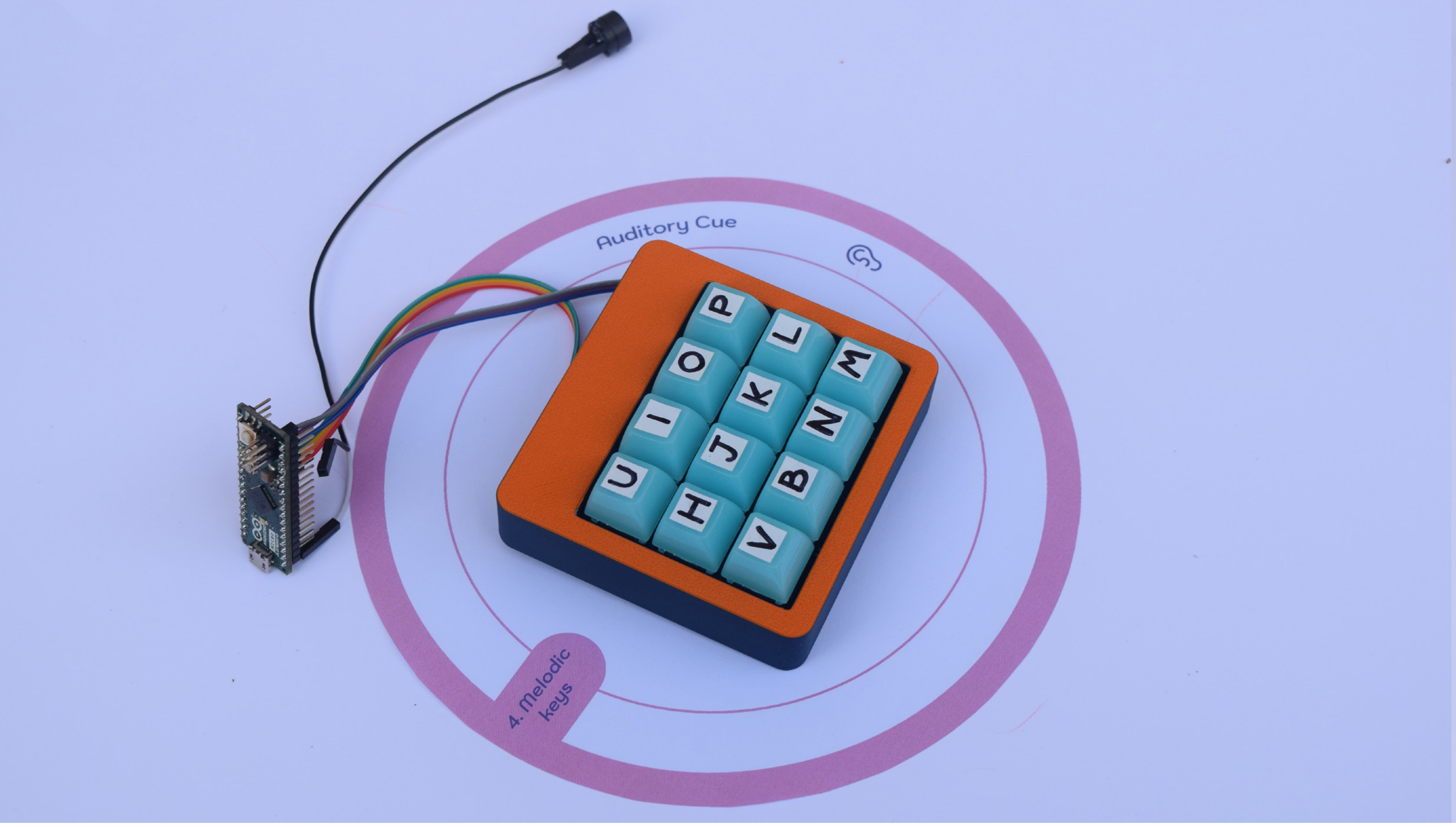


Fig. 47 Vibrating palm rest

FEATURES

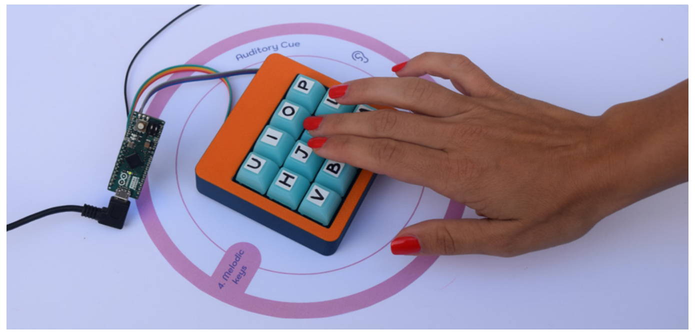


Fig. 48 Rhythmic keys

1. Rhythmic keys
Each time a key is pressed, the user hears an auditory cue. This sound provides immediate feedback, enhancing the typing experience by reinforcing the action of each keypress.

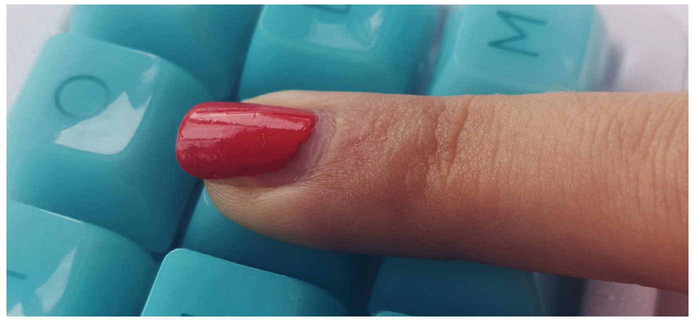


Fig. 49 Stuck Finger

2. Stuck finger
If a user's finger gets stuck on a key, the keyboard will increase the intensity of the metronome sound to provide auditory feedback, prompting the user to lift their finger. To prevent repeated letters, the keyboard will register only a single keypress, even when continuous pressure is applied.

Fig. 50 Freezing prevention

3. Freezing Prevention
If the user does not press any keys for five seconds, the keyboard emits multiple sounds to prompt the user to continue typing. The user should be able to adjust the time delay for this function to suit their preferences.

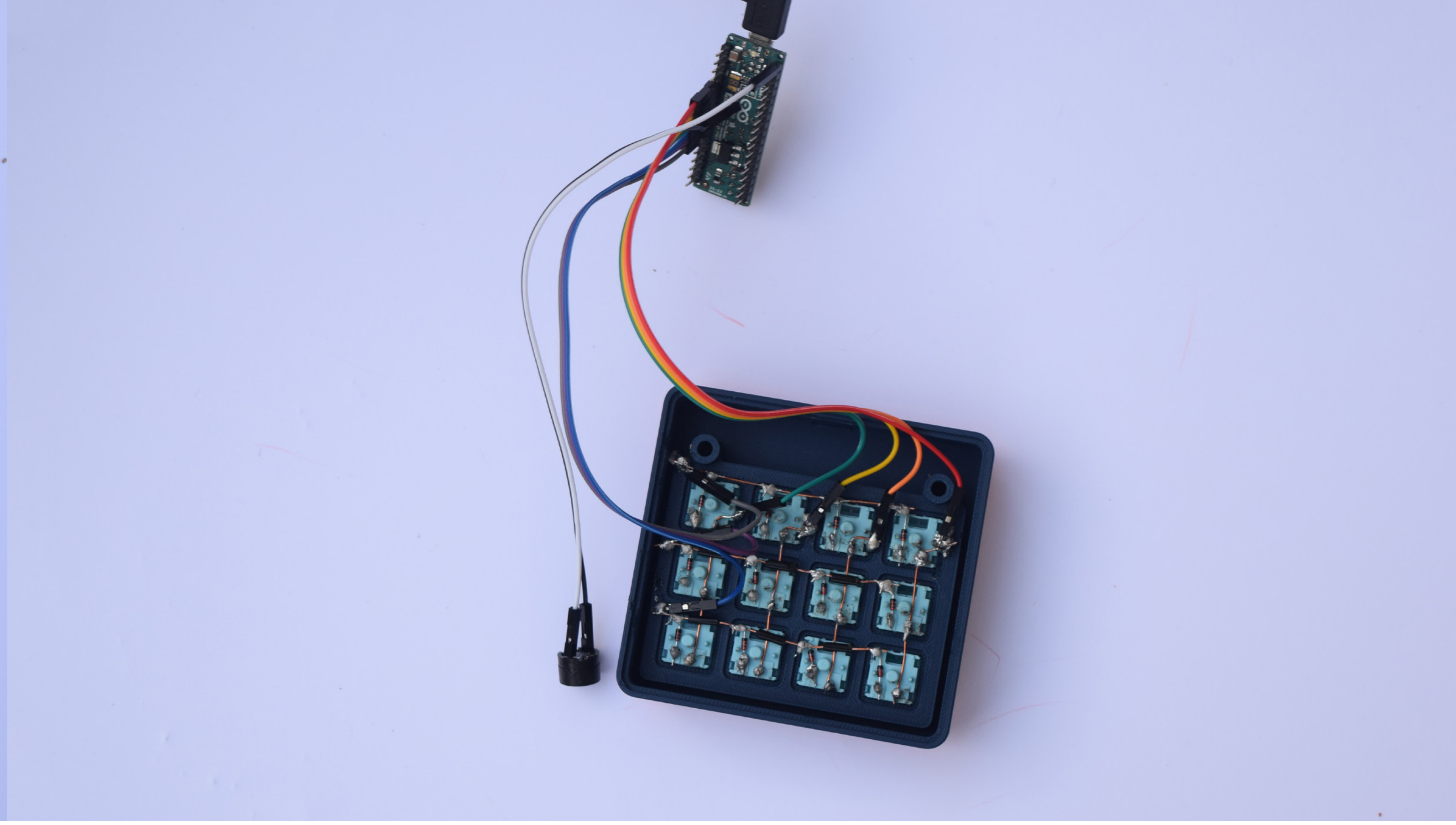


Fig. 51 Hardware

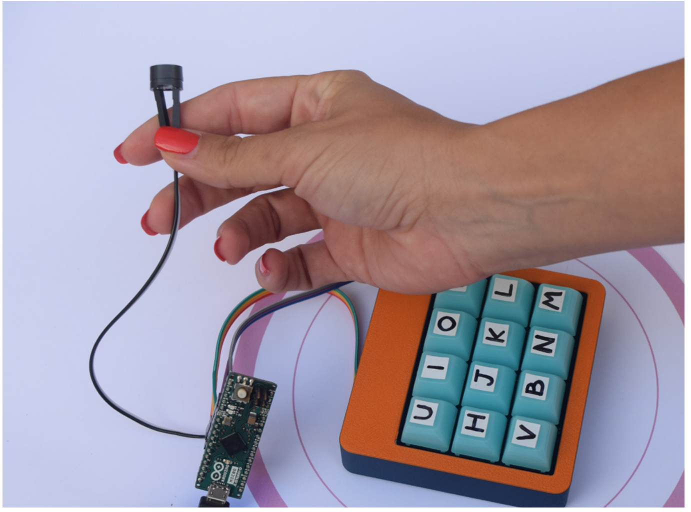


Fig. 52 Passive buzzer

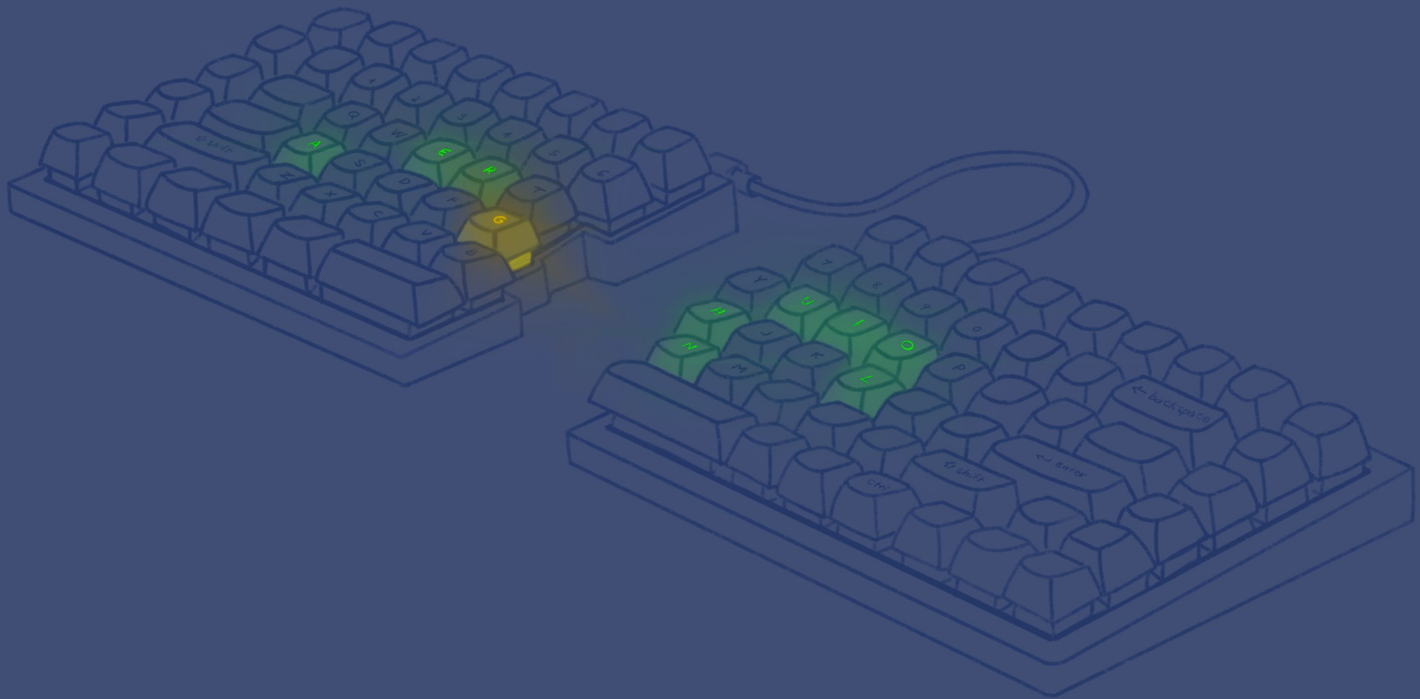
PROTOTYPE

This prototype is a hand-wired matrix keyboard equipped with a buzzer for auditory feedback. While the passive buzzer cannot fully replicate the metronome sound, it is sufficient to provide the user with an effective auditory experience, enabling them to engage with the three features explained previously. (Further details can be found in the appendix E).

NEXT POSSIBLE LETTERS

6.7 Concept 5

This concept improves typing efficiency and focus by using visual cues. When a key is pressed, it lights up in yellow to provide immediate feedback. At the same time, the most likely letters that could follow light up in green, offering suggestions based on the current context. As the user types, the system leverages AI to refine these predictions, reducing the number of highlighted keys as the word becomes more predictable. By lighting up only the most relevant keys, the system minimizes distractions, keeps the user focused, reducing cognitive load during typing.



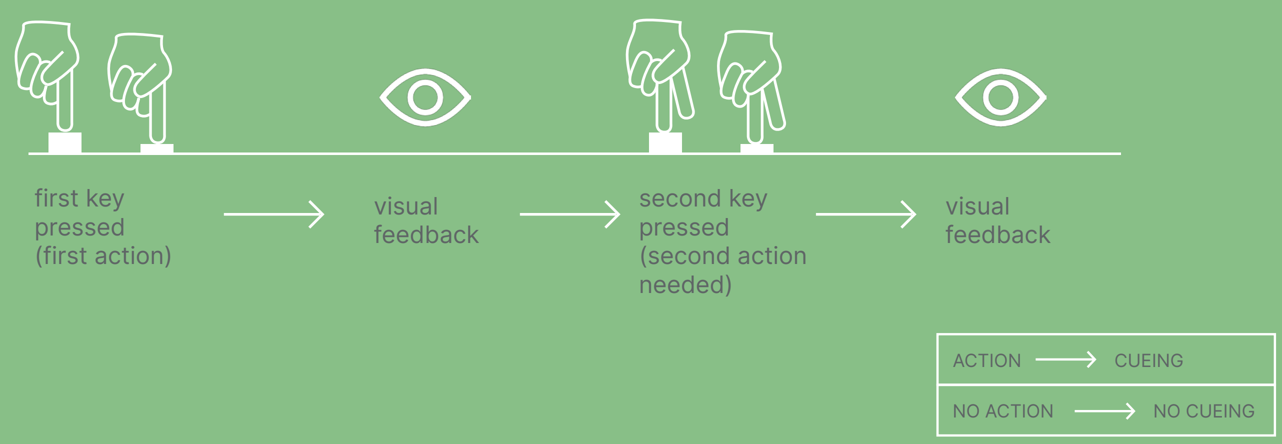


Fig. 53 Action-Feedback Diagram

Fig. 54 Prototype Concept 5 (Turned off Keyboard)

FEATURES

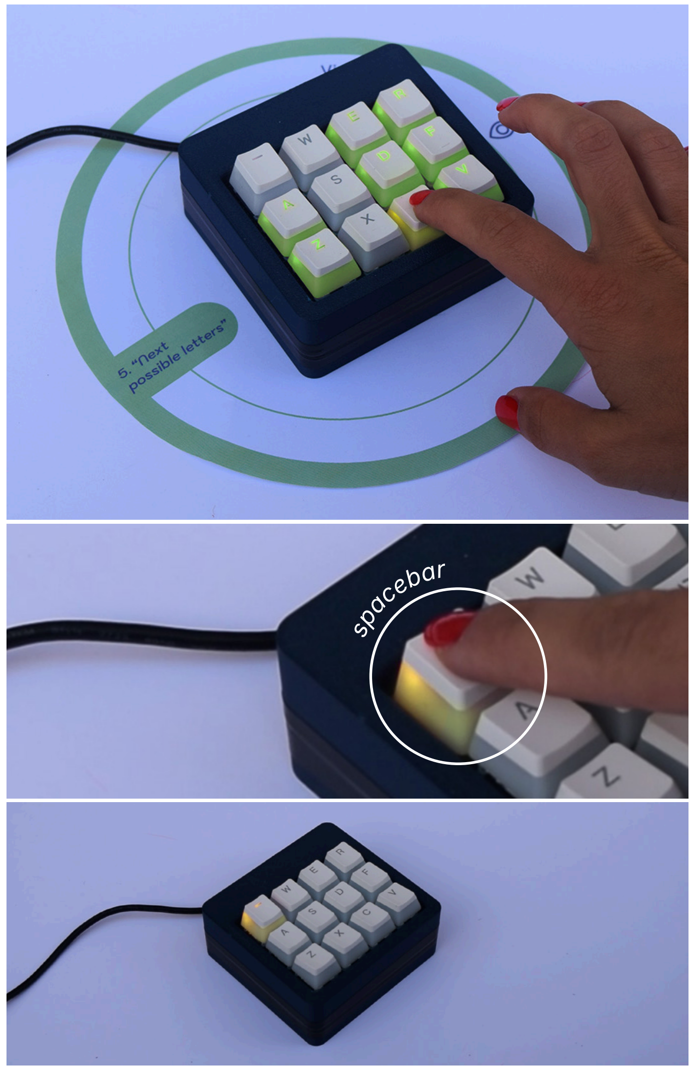


Fig. 55 Concept 5

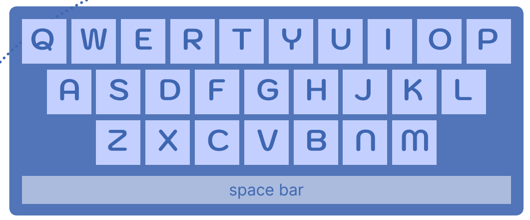
1. Key Lighting on Press
Keys light up in **yellow** when pressed, providing immediate visual feedback to the user.

2. Suggested Next Letters
Based on the selected language, the most probable letters that are likely to follow the pressed key light up in **green**, helping guide the user toward the next character.

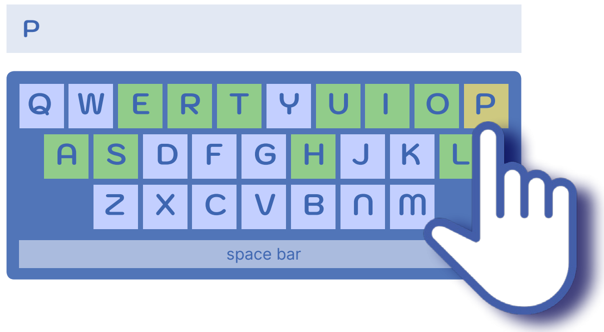
3. AI-Powered Typing
As the user types, the system uses **AI** to predict and refine the suggestions. The more the user types, the fewer keys light up, as the AI narrows down the most likely next letters, increasing typing speed and focus.

4. Spacebar Function
When a word is completed and the **spacebar** is pressed, all keys turn off, signaling the end of the current word and resetting the display for the next input.

HOW IT WORKS

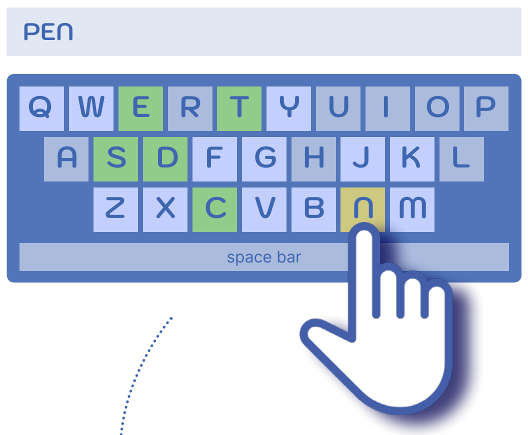


Turned off keyboard

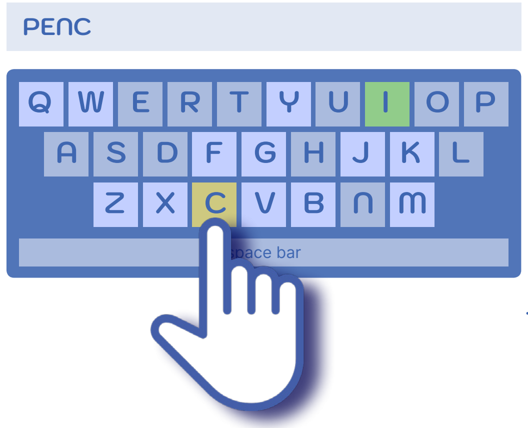


When the user presses the letter P, it lights up in yellow. The possible letters that can follow light up in green: A, E, H, I, L, O, R, S, T, U. These letters represent the only valid continuations of "P" in English words, such as PA ("park"), PE ("pen"), and PI ("pin").

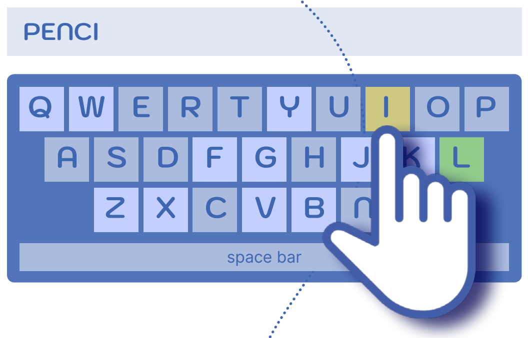
When the user presses the letter E, it lights up in yellow. In green (possible letters after "PE"): A, C, D, L, N, R, S, T These letters frequently follow "PE" in English words (e.g., "PEA" for "pearl", "PEN" for "pen", "PER" for "person").



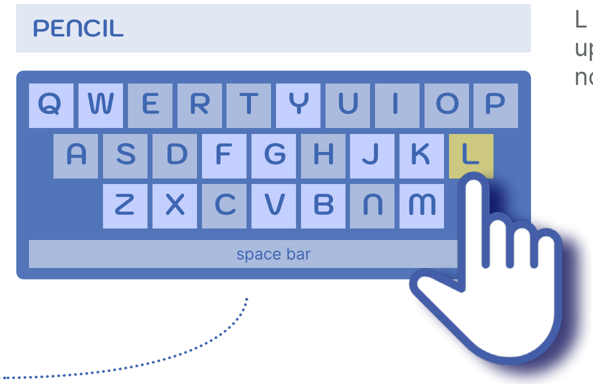
The user presses the letter N. In green (possible letters after "PEN"): C, D, E, S, T. These are common after "PEN" (e.g., "PENC" for "pencil", "PEND" for "pendant", "PENS" for "pens").



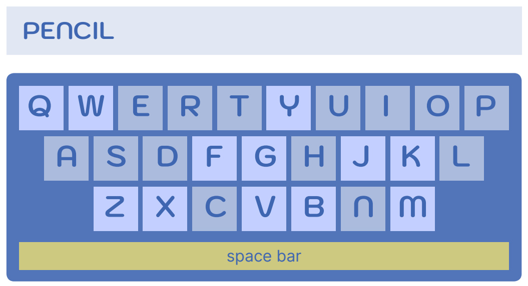
The user presses the letter C. In green, the only possible letters after "PENC" is the letter I.



The user presses the letter I. In green (possible letters after "PENCI"): L



L in yellow. No letters light up in green as "PENCIL" is now a complete word.



Once the word is finished the spacebar is pressed to turn off the keyboard and move on to the next word.

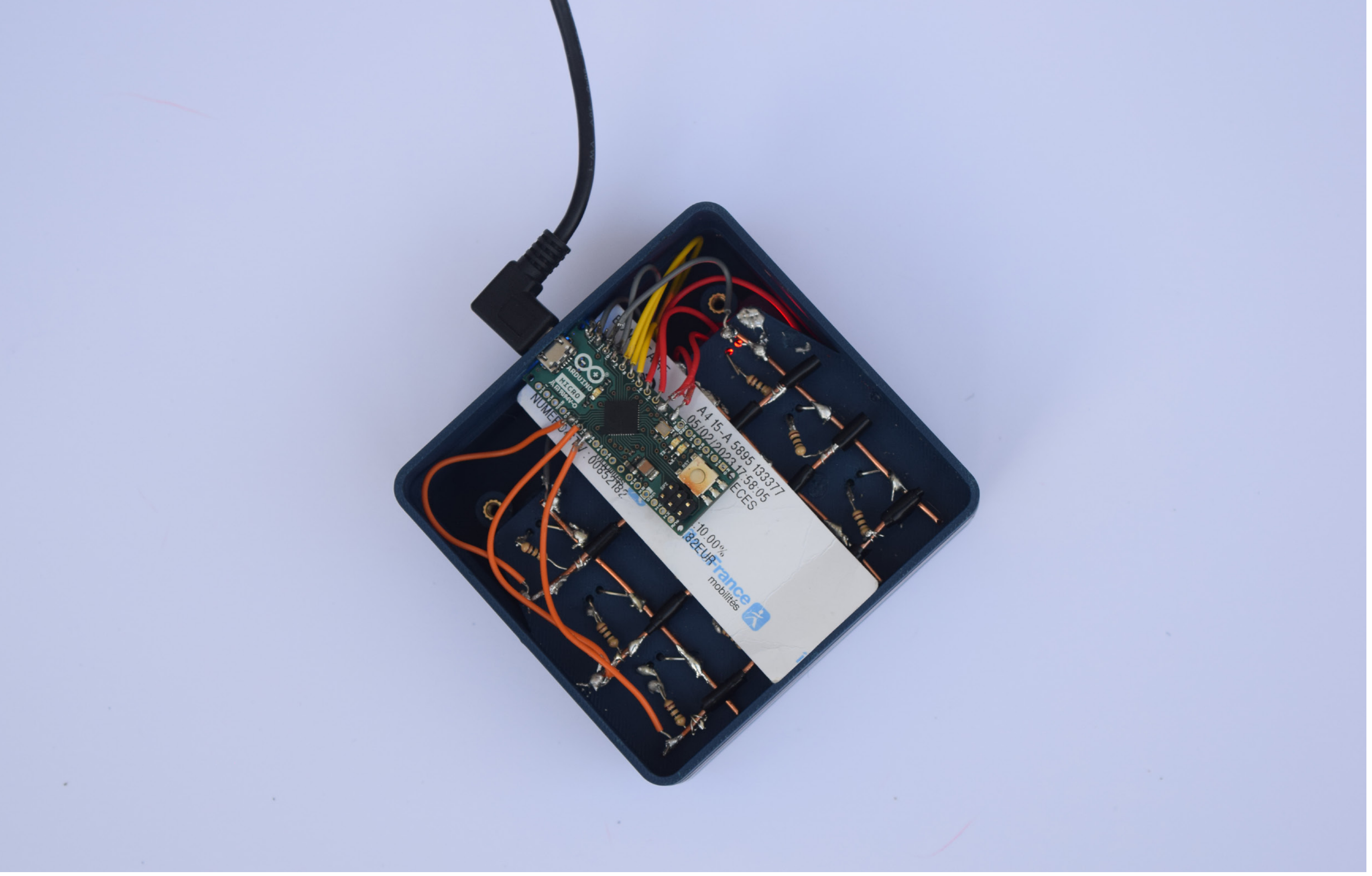


Fig. 56 Hardware

Fig. 57 Turned on prototype

PROTOTYPE

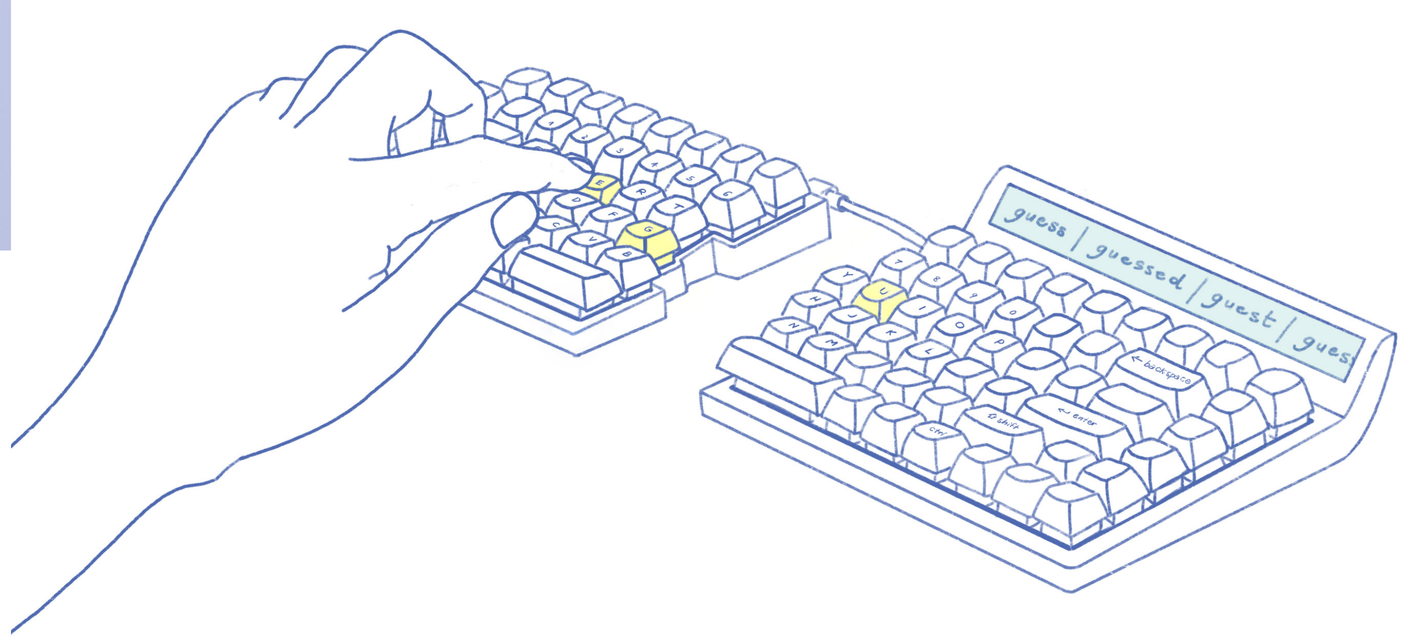
This prototype is a hand-wired matrix keyboard, with each key paired with an individual LED to provide visual feedback. The LEDs are also connected in a matrix configuration. Red LEDs were chosen for the prototype due to their lower voltage requirements, making them more practical during the initial development phase.
Although this version does not feature full AI integration, it effectively demonstrates the concept of suggesting the next letters. When a key is pressed, the corresponding LEDs light up to indicate possible following letters, allowing users to test the core functionality of predictive typing.
The spacebar, located in the left corner of the prototype, functions as described in the concept: once a word is completed and the spacebar is pressed, all the keyboard's letter LEDs turn off. (Further technical details can be found in Appendix E).

WORD SUGGESTION

6.8 Concept 6

This concept introduces a familiar feature: the word suggestion function commonly found on smartphones (Fig. 58). The keyboard is equipped with an LED monitor that displays word suggestions as certain keys are pressed. For example, if the user types the letters G, U, and E in sequence, the screen will suggest words like "guess," "guessed," and "guest." At this point, the user can select the desired word directly from the touchscreen monitor, reducing the need for continued typing and minimizing fatigue.

Fig. 58 Text prediction on smartphones



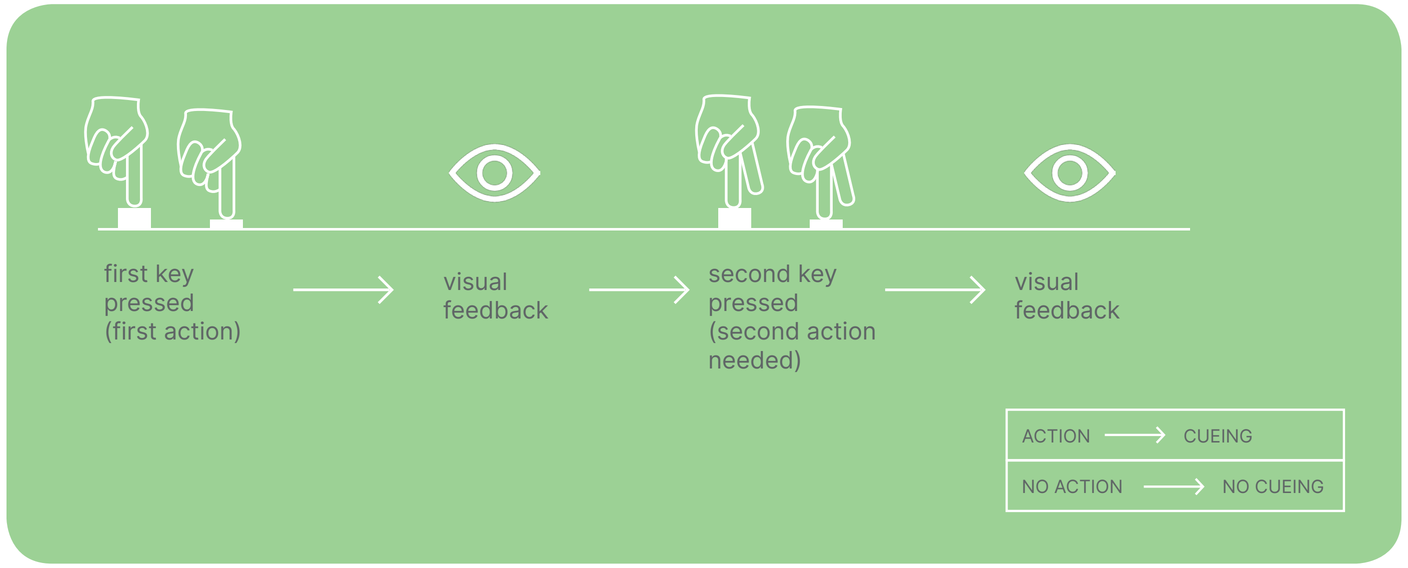


Fig. 59 Action-Feedback Diagram

Fig. 60 Concept 6

FEATURES

Fig. 61 Touch-screen

1. Word Suggestion
As users type, the keyboard dynamically displays the most probable word predictions based on the letters entered, streamlining the typing process and reducing physical effort.

2. AI Implementation
This concept implements AI technology to learn from the user's typing patterns and frequently used vocabulary over time. This allows for more personalized and accurate word suggestions, making typing faster and more intuitive.

3. Language Selection
Users must be able to select their preferred language for typing. This feature ensures that word suggestions and predictions are tailored to the chosen language, improving accuracy and ease of use across various linguistic contexts.

7. Testing

7.1 Purpose of the investigation

The purpose of this investigation is to evaluate how individuals with Parkinson's disease (PD) interact with and experience the features incorporated into different design concepts. Given the complexity of Parkinson's, multiple methods have been explored to gain a deeper understanding of how individuals perceive and engage with the prototypes.

7.2 Preliminary focus group

MEASUREMENT
A preliminary study was conducted to determine whether participants had a clear preference for one cueing technique over another. From this, three main research questions were formulated:

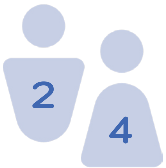
1. What are the users' key priorities when it comes to enhancing their computer experience?

2. Is there a particular cueing technique that stands out as the most effective or preferred?

3. How do users perceive and evaluate the presented design concepts?

METHOD
A focus group was conducted to gather valuable feedback and diverse perspectives on the various design concepts. This session took place during the initial phase of the project and involved an open discussion.

PARTICIPANTS
Six people participated in the focus group, all Dutch citizens diagnosed with Parkinson's, as they are the target group for this research. The group included four women and two men to ensure a more heterogeneous sample. All participants were self-sufficient and regular computer users.



STIMULI
Participants were shown a presentation, accompanied by videos highlighting various conceptual features.

APPARATUS
A laptop and projector were used to display the presentation and videos, while a smartphone with a voice recording app captured the participants' discussions.

PROCEDURE
Participants were first given a consent form to sign. Following this, they attended a presentation delivered by the researcher, during which they provided feedback. The presentation began with a brief introduction outlining the research objectives and the goals of the graduation project. Various design concepts were then explained, followed by an open discussion to gather participant insights. The researcher moderated the discussion throughout the session.
The concepts were presented by categorizing the features into auditory and visual cueing techniques. Although no concepts related to somatosensory cueing were presented at the time of the focus group, participants were asked whether

Fig. 62 Concepts presented in the first study

they believed this feature was worth exploring further. Referring to the previous chapter, concepts 4 (auditory cue), 5 (visual cue), and 6 (visual cue) were presented during the session, showcasing only their basic features, as they were still in development. The presentation in Appendix F represents the material shown to the participants.

MEASURES
To evaluate the functionality and emotional response to the different concepts, participants were asked a series of questions:

1. Do you think this feature could improve your interaction with the computer keyboard? Why?

2. How does it make you feel?

3. Do you see any other opportunities related to this feature?

4. Do you think that haptic feedback (vibration) could be useful? Why?

5. Do you have any other ideas on how to improve your experience while using a computer keyboard?

RESULTS
Fig. 63 presents the key results of the group's feedback.

CONCEPTS	FEEDBACK
Melodic keys	• Everyone agreed that sound might be annoying.
Nex possible Letters	• *"Colors should be bright, but I like it as cueing".* • *"I would like to have an easy way to switch from English to Dutch".* • *"I like this idea. It is important to be able to deactivate it quickly".*
Words suggestion	• *"I like this idea, it is like Outlook. I want to press the spacebar to select the right word".*
Haptic feedback	• *"Yes, haptic feedback could be useful. Everyone has tremors, even if they are not visible".* • *"Press the key and get vibration, it would be good".* • *"To avoid being stuck on a key, you press the key and after a few second goes back".* • *"Vibration on the wrist / palm could be useful".*
General feedback	• Everyone agreed that maintaining their flow while typing is more important to them than speed or other issues. Keeping the flow is a top priority, and they feel most frustrated when they are unable to do so.

Fig. 63 Results

DISCUSSION
Revisiting the research questions, the following answers can now be provided:

1. What are the users' key priorities when it comes to enhancing their computer experience?

The focus group revealed that the primary priority for users is maintaining their flow while typing. Although the project focuses on the symptom of bradykinesia, this emphasis on maintaining flow must be considered a higher priority than speed during the design process.

2. Is there a particular cueing technique that stands out as the most effective or preferred?

No specific cueing technique emerged as the most preferred or effective. However, auditory cueing was disliked, as participants found the sound distracting and annoying. Despite this, many existing products on the market use metronome sounds to assist people with freezing of gait. It's important to note that a limitation of this study was that users did not physically test the various cueing techniques. Visual cueing was more appreciated, sparking curiosity among participants. Additionally, users suggested that somatosensory cueing (haptic feedback) should remain a focus of the project, offering suggestions to test haptic feedback on different parts of the body, such as the fingertips, palm, and wrist.

3. How do users perceive and evaluate the presented design concepts?

Participants appeared engaged by the visual concepts, but physical testing is necessary to provide more detailed and constructive feedback.

CONCLUSION
In conclusion, this preliminary study has been essential in shaping the project's direction, underscoring the importance of focusing on multiple cueing techniques simultaneously.

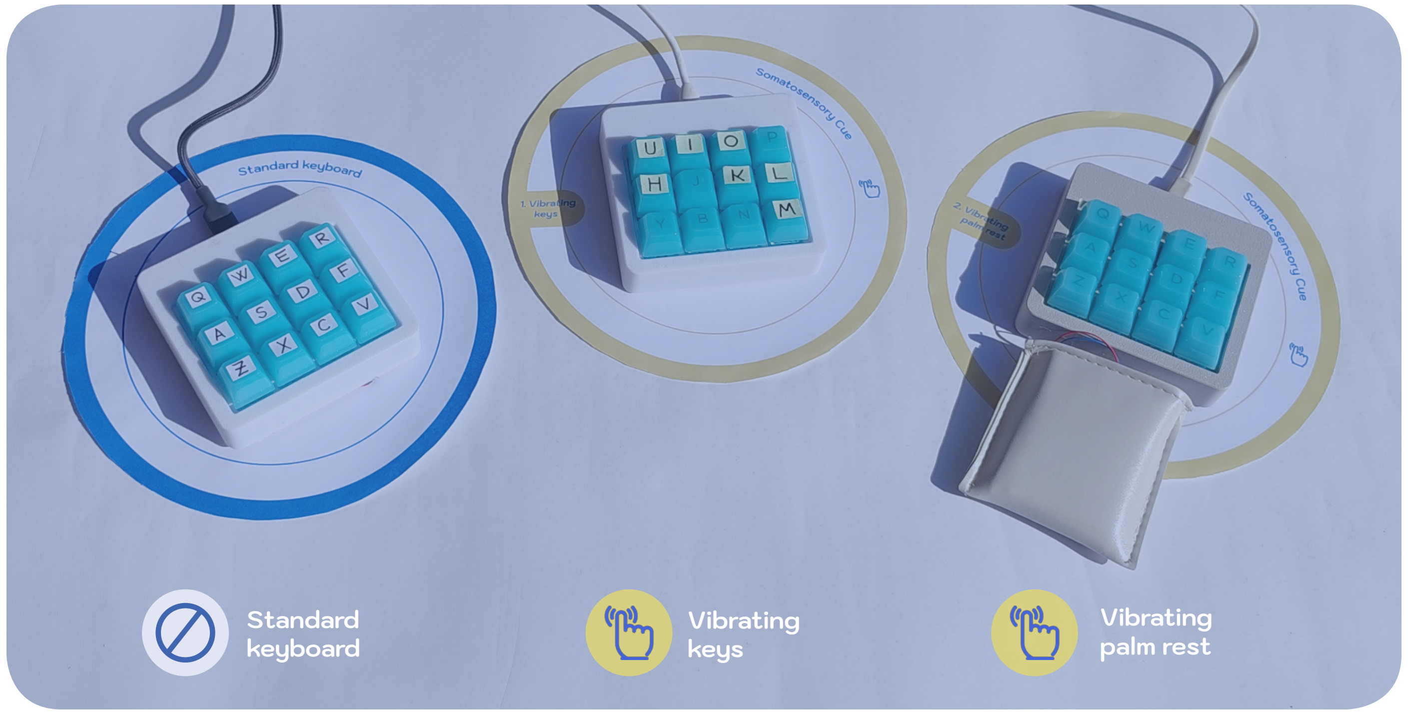


Fig. 64 Prototypes presented in the keyboard test

7.3 Pilot Keyboard test

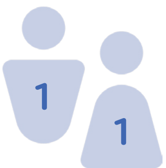
MEASUREMENT
A pilot study was conducted to assess whether objective data could be collected on the effectiveness of cueing techniques in mitigating the effects of bradykinesia. This research focused specifically on somatosensory cueing, particularly haptic feedback. The study aimed to answer two key research question:

1. Is it possible to develop an objective test to evaluate the proposed prototypes?

2. Does haptic feedback reduce the symptoms of bradykinesia when implemented in a computer keyboard?

METHOD
A typing performance test was conducted to assess users' motor skills, speed, and accuracy when interacting with different keyboard prototypes. This test evaluates the users' ability to repetitively tap specific keys or alternate between key combinations as quickly as possible within a set time frame (60 seconds). It is commonly used in bradykinesia assessments for Parkinson's disease, following the methodology outlined in the research paper Bradykinesia assessment in Parkinson's disease source: AI for Health, Bradykinesia Assessment (Bradykinesia Assessment in Parkinson's Disease - AI for Health, n.d.). This test was selected as it provides a standardized method for evaluating motor impairments in typing tasks.

PARTICIPANTS
As this was a pivot test, two participants were selected: one individual with Parkinson's disease and one without.



STIMULI
Participants interacted with three different keyboard prototypes, each consisting of 12 keys:
- **Prototype 1.** Standard Keyboard (without haptic feedback): This served as the control condition, with no haptic feedback provided.
- **Prototype 2.** Keyboard with Vibrating Palm Rest
- **Prototype 3.** Keyboard with Vibrating Switches

Fig. 65 Prototype 12 keys

PROCEDURE
Participants were first asked to sign a consent form. They were then instructed to interact with the prototypes by performing specific typing tasks designed to evaluate their performance. Each task required participants to tap specific keys or alternate between key pairs as quickly as possible for 60 seconds. The tasks were as follows:

Task 1: Type a single key (e.g., key X, figure X) as quickly as possible for 60 seconds, first using the left hand, then the right hand.
Task 2: Type two adjacent keys (e.g., keys S and D, figure X) alternately for 60 seconds, first with the left hand, then with the right hand.
Task 3: Type two distant keys (e.g., keys A and F, figure X) alternately as quickly as possible for 60 seconds, first with the left hand, then with the right hand. (The complete exercise can be found in appendix G).
Performance data were then collected and analyzed to determine whether any of the prototypes significantly improved typing speed, reduced delays, or enhanced accuracy, particularly for participants with Parkinson's disease.

MEASURES
To evaluate the functionality of the test, the letters typed during the tasks were recorded and counted.

RESULTS
Prototype 1 (Standard Keyboard):

The performance gap between the PD and non-PD users was minimal for single key taps but became noticeably larger for tasks involving adjacent and distant key taps, highlighting the increased difficulty of more complex movements for the PD user due to bradykinesia.

Prototype 2 (Keyboard with Vibrating Palm Rest):

There was no notable difference between the PD and non-PD users. Although the PD user reported improved rhythm and less fatigue, the overall performance gains remained small.

Prototype 3 (Keyboard with Vibrating Switches):

This prototype showed the most apparent improvement for the PD user, particularly in single and adjacent key tasks, with increased speed and accuracy.

The user with PD preferred the vibrating prototypes, noting better rhythm and reduced fatigue. While they felt more in control with the vibrating switches, they were unsure whether the vibration itself made the difference. Interestingly, they found sound feedback more important than vibration but couldn't say for certain that the haptic feedback prototypes were effective. The user also emphasized that speed wasn't their main concern. (Complete results can be found in Appendix G.)

DISCUSSION
Although the third prototype appeared to perform slightly better than the others, several issues arose during testing. The prototypes lacked the reliability of market-ready products, and at times, key presses weren't registered, which made the results less consistent. Additionally, the test duration was too long, requiring too much energy from both the PD user and the non-PD user. To address the research questions:

1. Is it possible to develop an objective test to evaluate the proposed prototypes?

Not fully. Bradykinesia is a complex condition that fluctuates daily and varies greatly between individuals. For consistent results, the prototypes need to be fully refined. Additionally, users need time to experience the product in real-life settings, performing familiar tasks comfortably, to accurately assess its effectiveness.

2. Does haptic feedback reduce the symptoms of bradykinesia when implemented in a computer keyboard?

We cannot definitively say that haptic feedback on a keyboard reduces bradykinesia. While existing research supports this idea, this specific test did not provide clear evidence at this stage of the project.

CONCLUSION
As the user pointed out, and as confirmed by the earlier focus group, while speed is a quantifiable metric affected by bradykinesia, it is not the primary concern for individuals with PD.

The focus should instead be on the user's subjective experience and perception. This pilot test demonstrated that continuing with objective testing of this kind is not productive.
Instead, another focus group is needed to gather deeper insights, with an emphasis on users' personal experiences, which offer greater value. Given the user's emphasis on the importance of rhythm, exploring prototypes with auditory feedback remained part of the project's scope.

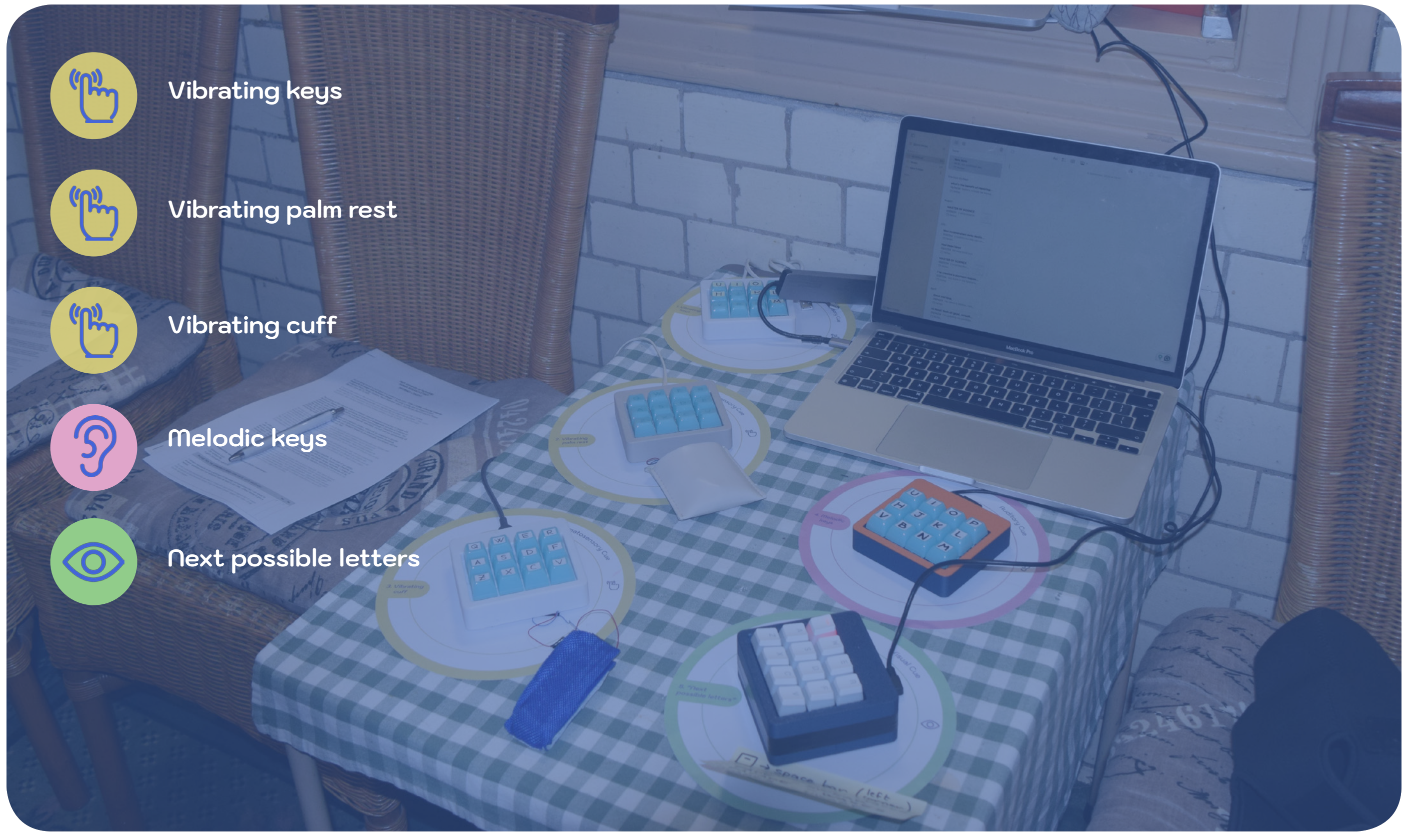


Fig. 66 Focus group set-up

7.4 Focus group

MEASUREMENT
A second focus group was conducted to gather valuable feedback and diverse perspectives on prototypes developed for somatosensory, visual, and auditory cueing, as well as a final prototype that integrated multiple features. At this point in the project, it became clear that definitively determining what works best was challenging. Therefore, the research focused on identifying preferred directions and assessing whether any approaches could be ruled out. This led to the formulation of three main research questions:

1. Is there a particular cueing technique that stands out as the most preferred?

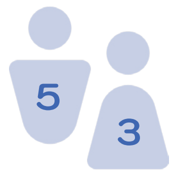
2. How do users perceive and evaluate the presented design concepts?

3. Are there any features or techniques that participants do not find valuable?

METHOD

A focus group was selected as the method to obtain valuable feedback and diverse perspectives through a co-design session, where participants were encouraged to freely share their opinions throughout the process. This approach was chosen because research has demonstrated that individuals with Parkinson's have varying needs and symptoms.

PARTICIPANTS
Eight individuals participated in the focus group, all of whom were Dutch citizens, the target group for this research. The group consisted of three women and five men, all self-sufficient and regular computer users. Seven participants had Parkinson's Disease, while one had Multiple Sclerosis (MS). This individual was included due to the similarities between MS and PD. Both MS and PD can impact physical and cognitive functioning. Several symptoms of MS and PD, such as fatigue, muscle spasticity, muscle pain, and changes in cognitive functioning, can interfere with computer typing (Fletcher, 2022). These symptoms can lead to difficulties with fine motor control, coordination, and overall interaction with a keyboard.



STIMULI
Participants were shown a presentation accompanied by videos that highlighted various conceptual features. They also interacted with several prototypes. Small prototypes, each containing 12 keys, were developed to demonstrate individual features, which could potentially be integrated into the final design:

Feature Prototypes (Fig. 66):
Prototype 1: Concept 1 - Keyboard with vibrating switches
Prototype 2: Concept 2 - Keyboard with a vibrating palm rest
Prototype 3: Concept 3 - Keyboard with a vibrating cuff
Prototype 4: Concept 4 - Keyboard with rhythmic keys
Prototype 5: Concept 5 - Keyboard "Next Possible Letters"
Prototype 6: Concept 6 - Keyboard with "Word Suggestions"
All concepts were presented as outlined in Chapter 6.

Final Prototype (Figs. 67 and 68):
The final prototype is a full keyboard equipped with palm rests, cuffs, and a controller to manage various features. This keyboard integrates all six concepts (1-6) into a single design, providing a comprehensive demonstration of all functionalities to facilitate open discussion and physical evaluation of the final product.

Fig. 67 Final prototype

The controller (Fig. 69) includes several controls:
The top button, marked with a musical note icon, toggles sound (concept 4) on and off and adjusts its volume. The second button controls the vibration, toggling it on and off, and adjusts its intensity (concepts 1, 2, and 3). The third button, featuring a sun icon, turns on/off and adjusts the light intensity for concept 5. Language selection (Dutch/English) sets preferences for Concepts 5 and 6. A freezing prevention controller (concepts 2, 3, and 4) allows users to set a feedback interval, choosing vibration or a metronome beat after a specified number of seconds. The complete presentation can be found in Appendix H.

PROCEDURE
Participants were first given a consent form to sign and a booklet containing questions to help them take notes and guide them through the co-design session. After completing the consent forms, they attended a presentation delivered by the researcher. This presentation began with a brief introduction outlining the research objectives and the aims of the graduation project. Following the introduction, various design concepts were explained, and participants were invited to interact with the prototypes. This hands-on interaction was followed by an open discussion to gather participant insights. The presentation materials provided to the participants can be found in Appendix H.

MEASURES
To evaluate the functionality and emotional response to the different concepts, participants were asked a series of questions:

1. Do you think this feature could improve your interaction with the computer keyboard? Why?
2. How does it make you feel?
3. Do you see any other opportunities related to this feature?

Fig. 68 Components

Fig. 69 Controller

RESULTS

Below are the focus group results. Comments are categorized into positive, negative, and neutral. (Complete answers can be found in Appendix I).

Positive feedback | *Negative feedback* | *Neutral feedback*

CONCEPT 1 Vibrating keys

• Do you think this feature could improve your interaction with the computer keyboard? Why?

Positive feedback:
- Yes, it basically takes over the function of the hand, when ending pressing a key is not "sensed"/defined. Hand is triggered to end pressuring.
- Yes, more interaction with the computer. More feedback. Better results. Fewer mistakes.
- I think so, but it's difficult since I type two handed.
- Yes, but it should be adjustable.

Negative feedback:
- No, it seems to slow things down instead.
- Too distracting
- It doesn't seem helpful to me; the noise disturbance seems more irritating.

Neutral feedback:
- You should use it for a longer period of time.

• How does it make you feel?

Positive feedback:
- Opens opportunities / Hope!
- Would be happy if it worked.
- I'm ok with it.

Negative feedback:
- A little strange
- Restless
- Unrelaxed / Unpleasant
- Not good, irritation

Relevant comments

- Users would like a feature to adjust the volume of the vibration motor.
- They want to avoid disturbing those around them.

Key findings

Feedback on Concept 1 is mixed. Some users appreciate the benefits, such as increased interaction and enhanced feedback, while others express concerns about practicality and noise. Notably, one user mentioned that the vibration integrated into the switch seemed to prompt their hand to complete the action of pressing the key. An important suggestion was to make the vibration feedback adjustable in intensity, which has already been incorporated into the final design. This feature could potentially change the opinions of those who initially disliked the concept, as their primary concern was the noise generated.

CONCEPT 2 Vibrating palm rest

• Do you think this feature could improve your interaction with the computer keyboard? Why?

Positive feedback:
- Yes, but I feel there is too much interaction. Too many senses are touched.
- I preferer than 1. Less distracting.

Neutral feedback:
- With a wristband/ smartwatch, it might be more comfortable.

Negative feedback:
- No, irritates me.
- No, not for me. Every vibration makes me restless.
- Too much vibration and sound.
- No, I cannot think in what way this will be helpful.

• How does it make you feel?

Positive feedback:
- Way better than the first one.
- Better than keyboard feedback (concept 1).

Negative feedback:
- Getting more stressed.
- This will stress me out.

Key findings

Opinions on Concept 2 are divided. While some users prefer this option, seeing it as an improvement over the first concept, others have differing views. Those who provided positive feedback acknowledged it as a step forward compared to Concept 1. However, many users still reported feelings of stress and irritation caused by the vibration and the noise it generates.

CONCEPT 3
Vibrating cuff

• Do you think this feature could improve your interaction with the computer keyboard? Why?

Yes.

Better than number 2, but seems distracting when working at the desk due to “hand cuffs”.

It seems to keep the hand calm.

Better could be helpful on the wrist.

This is nice, but the feedback remains irritating.

• How does it make you feel?

Relaxed

Calm

It feels comfortable but not sure whether it works.

Key findings

This is the most well-received concept among the first three, with only two out of eight people still finding it distracting. The majority appear to appreciate it, expressing feelings of calmness and relaxation.

CONCEPT 4
Rhytmic keys

• Do you think this feature could improve your interaction with the computer keyboard? Why?

I don’t like monotonous sounds.

Sound is annoying.

No, really annoying.

No, too many sensors.

Irritating sound.

• How does it make you feel?

Not relaxed, too much noise.

Really annoying and distracting.

Conclusion

This concept received exclusively negative feedback. One person noted that although she uses music to relax, she still disliked this concept, even though metronome sounds are known to help mitigate Parkinson’s symptoms. The general consensus was that the sound is too irritating, likely because typing, unlike walking (where a metronome is often used in products for people with Parkinson’s) requires focus and mental effort. The intrusive sound seems to interfere with this concentration.

CONCEPT 5
Next letters suggestions

• Do you think this feature could improve your interaction with the computer keyboard? Why?

Might work for people who do not type “blind” but seems quite complicated / confusing.

In the long run could help with long distances.

No, makes me think about my phone type feature which I do not like.

For people who don’t type blind it could be helpful.

No because I type blind, I don’t look at my keyboard.

For me a combination of this with sotware for speech detection could be helful.

Doesn’t help with touch typing.

No need for it.

• How does it make you feel?

Too much stress.

Relevant comments

• One user liked the idea of AI learning from her typing behavior, vocabulary, and language. She expressed interest in enabling word completion by pressing the spacebar.

Key findings

Many people mentioned that they type without looking at the keyboard, so this feature would not be helpful for them. However, they do see potential benefits for those who do not type this way. This concept did not evoke much of an emotional reaction, with only one user reporting a sense of stress.

CONCEPT 6
Word suggestion

• Do you think this feature could improve your interaction with the computer keyboard? Why?

Function already exists (in different form) in most social media / microsoft programmes.

I do not have problem with the flow.

I don't like the separate monitor, too complex, too much time.

Sounds interesting, but it doesn't help to type faster.

• How does it make you feel?

Not relaxed.

Key findings

Only one user mentioned that this concept sounds interesting. Another user suggested a better integration of this feature, as they did not like the use of a separate monitor. Only one user responded to the question about their feelings, stating that they did not feel relaxed.

ADDITIONAL NOTES

Difficult to address

• Difficult to adress because everyone has different needs.
• "I have a slow arm due to Parkinson's".
• Typing - "I use both hands, but only the left side is affected by the symptoms".
• "I really fancy that you designed a keyboard with multiple solutions because different people have different needs ".

Key height

• The height of the keys is important.

Testing in daily tasks

• "It would be nice to have the keyboard and really try it out for a day."
• "You could learn a lot by recording and observing how people with Parkinson's disease type."

Speech recognition

• "I would like something that recognizes when I'm making mistakes and asks if I want to switch to speech recognition."

Programmable keys

• "I have difficulty with small movements, so I use a keypad. You can program shortcuts or even entire sentences on it, either partially through hardware or software."

Separate keyboard

• I need a separate keyboard instead of using the built-in laptop keyboard.

Posture

• Maintaining proper posture is crucial.

Effort to press

• The effort required to press the keys can be challenging.

ADDITIONAL COMMENTS

I am very positive / pleasantly surprised by option 1. Others will not work for me. Of course, given the nature of our disease, this is a very individual / semi objective opinion. Please keep in mind some people prefer a low / thin keyboard. I realized this is very difficult to achieve. Thank you for your efforts to help improve our quality of life. Grazie mille. Jan

Good research. I do not feel the need for more feedback for my computer. For people with MS (like me). I think we need less interactions with colours, sounds, light or vibration.

If the prototype can also be put into use, you will be able to see more results.

I really dislike sound: distracts me and others too. Vibration could be helpful. My preference: straps around the wrist. Light: not

In general for me the most important is the **height of the keys**, the effort it takes to press them. The size of the keys. In your prototype you focused on "borders" but the keys are still flat, but I think height is important to have a certain border nect to every key. NB: the keys soundn't be as hight as the "small" prototypes. Etra: I don't suffer from freezing but from tremor.

Fig. 70 Focus group

DISCUSSION

This co-design session revealed that, while vibration can serve as a positive trigger for users, the associated sound requires careful consideration. The most well-received concept involving vibration was wrist-based feedback, which elicited feelings of calm and relaxation, leading to the decision to further develop the haptic cuff. One user found fingertip vibration to be a valid solution, marking a significant achievement. However, palm rest vibration was the least appreciated of the three concepts. The wrist and fingertip feedback concepts may be more favorable, as they do not require users to maintain a fixed arm position.

As highlighted in the literature on cueing techniques, it is crucial to design a product for individuals with Parkinson's disease that is discreet and inaudible to those around them. The keyboard's intervention should not interfere with the user's ability to focus or complete tasks, making sound a significant concern for many participants. It is encouraging that the final prototype already incorporates adjustable vibration intensity, directly addressing this feedback.

The concept of rhythmic keys was universally disliked by participants. This sentiment mirrored feedback from a previous focus group with another group of individuals with Parkinson's, leading to the decision to remove this feature from the final design.

The "Next Letters Suggestion" concept was seen as potentially useful by individuals who rely on looking at the keyboard while typing, though many participants noted that they typically type without looking at the keys. Since this feature still needs to be tested on a full keyboard, the decision has been made to retain it in the final design. Further research is needed to explore alternatives to somatosensory cues and to better understand how users perceive visual cues, as several products on the market already utilize similar features.

The "Word Suggestion" concept received less enthusiastic feedback. While one participant found it interesting, most did not provide substantial input. One user commented that the feature felt overly complex, and given the positive results from haptic feedback, adding word suggestions seemed potentially confusing. Therefore, this concept will not be pursued further. The limited feedback toward the end of the session may have been due to the large number of concepts discussed (six plus a final one), which may have been overwhelming for a single focus group session.

It is important to note that the focus group setting did not allow users to interact with the prototype while sitting at a desk, as they would normally do when using a computer. This may have resulted in less extensive feedback and potentially less reliable results. Furthermore, the one-hour time frame was not ideal for this type of test. Future research should involve testing the prototype over a longer period, integrated into participants' daily tasks, to gather more accurate insights. Despite these limitations, the results obtained are still valuable at this stage of the design process.

The session also confirmed that individual preferences vary, even with regard to the height of the keyboard keys. A modular design, therefore, seems to be the most viable approach to accommodate these differences. Another important takeaway is that, in addition to cueing techniques, ergonomics play a critical role in addressing bradykinesia. The final model already includes features that support a natural posture, as it is a split keyboard that offers users the flexibility to position it according to their preferences, an essential requirement based on user feedback.

CONCLUSION

In conclusion, this co-design session was pivotal in shaping the direction of the project and provided valuable insights by identifying the concepts that generated the strongest positive or negative reactions, while deepening the understanding of user preferences. Future testing should involve providing participants with a fully functional model to use over several days, allowing for more comprehensive feedback in the next phase of the project.

8. OnCue

8.1 OnCue

OnCue is the culmination of this graduation project, designed to address the challenges faced by people with Parkinson's disease. It includes a specially designed computer keyboard and wearable cuffs, tailored to help alleviate the symptoms of bradykinesia and tremors. By transforming the keyboard, often seen as a barrier to using a laptop, into a reliable tool, OnCue provides access to essential digital activities such as work, social networking, online banking, and shopping. Its ultimate goal is to improve quality of life in an increasingly digital world that must be accessible to everyone.

8.2 Keyboard

This paragraph provides a detailed explanation of the wireless keyboard's features, highlighting its design elements and functionality. The keyboard can be paired with the computer through a Bluetooth connection.

- **Split Keyboard**: In the last 50 years, keyboard use has been associated with musculoskeletal pain in the hands, arms, shoulders, and neck. Research dating back to the 1920s indicated that a split keyboard design could alleviate muscle tension. Subsequent studies provided strong evidence that split keyboards can reduce upper body pain and discomfort by improving posture and reducing muscle strain (Rempel, 2008). For these reasons, the split keyboard was selected for as best option for people with PD.
- **Shortcuts**: Several Parkinson's associations and non-profit organizations provide valuable information on how people with Parkinson's can interact with technology more easily. One commonly recommended feature is Sticky Keys, an accessibility tool in operating systems that allows users to press modifier keys (Shift, Ctrl, Alt, or Windows/Command) one at a time instead of simultaneously. This feature is particularly beneficial for people with motor impairments, like Parkinson's disease, enabling them to execute key combinations with just one finger. However, using Sticky Keys can be time-consuming. To streamline this, I have integrated the four most commonly used shortcuts—copy, paste, cut, and undo (Ctrl + Z)—directly into the keyboard for easier access (Fig. 71) (Parkinson's UK Forum, n.d.).

Fig. 71 Shortcuts

Fig. 72 Arrow keys

- **65% keyboard**: This size provides an ideal balance between functionality and space efficiency, specifically chosen to accommodate the reduced movement amplitude caused by bradykinesia. Also known as a compact keyboard, the 65% layout removes the numpad and function keys found on full-sized keyboards but retains the arrow keys, which can be beneficial for the project target group (Fig. 72).

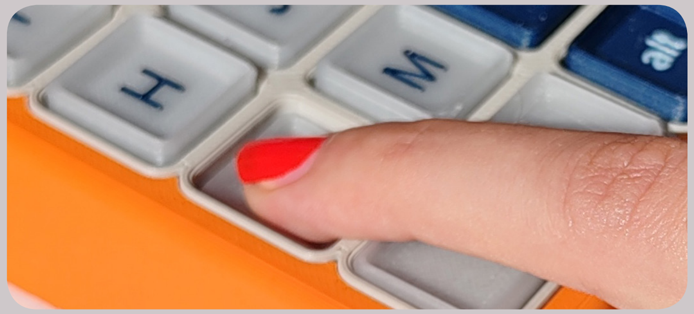
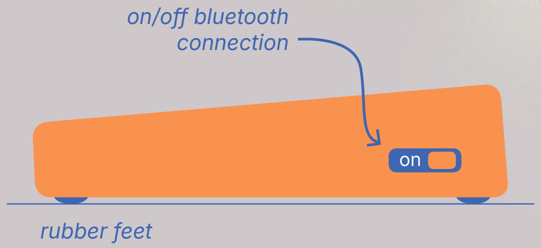


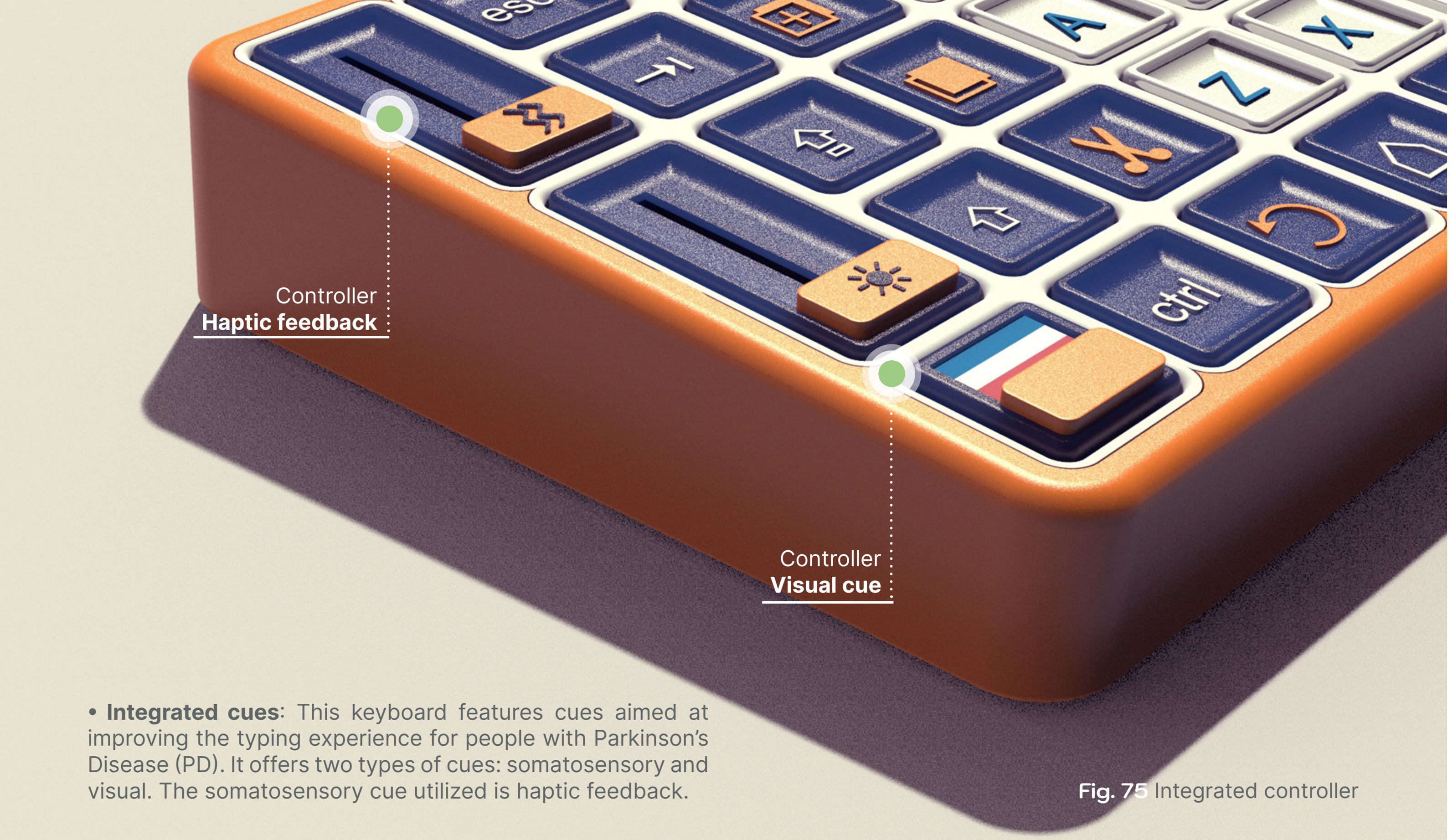
Fig. 73 Integrated keyguard

- **Integrated keyguard**: A product commonly sold to help people with PD use keyboards is the keyguard (a molded plastic overlay with holes that isolate each key, as explained on page 33).
OnCue integrates this concept into its design by providing small barriers between each key to prevent accidental key presses, aiding users in managing tremors (Fig. 73).



* PVC: Polyvinylchloride
PBT: Polybutylene terephthalate

Fig. 74 Split keyboard

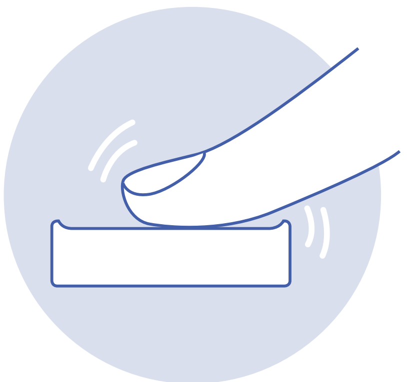


• **Integrated cues**: This keyboard features cues aimed at improving the typing experience for people with Parkinson's Disease (PD). It offers two types of cues: somatosensory and visual. The somatosensory cue utilized is haptic feedback.

Fig. 75 Integrated controller

Fig. 76 Haptic feedback

The haptic feedback is provided through motor-generated vibrations embedded within the switches. Users experience these tactile signals directly on their fingertips while typing. This feature is designed to offer sensory feedback that helps individuals with Parkinson's improve their typing accuracy and maintain a consistent rhythm. By delivering subtle vibrations with each keystroke, the system enhances the user's awareness of key activation, potentially reducing errors and providing additional sensory input to compensate for diminished tactile sensitivity.
This enhanced feedback aims to address the fine motor difficulties caused by bradykinesia, offering a more intuitive and responsive typing experience for those affected by slowed movement.



Features:

1. Vibrating keys (short press): Each time a key is pressed, the switch vibrates. The user can adjust the vibration intensity to their preference.

2. Stuck finger: If a user's finger remains stuck on a key, the vibration intensity will increase to provide stronger physical feedback, prompting the user to lift their finger. To avoid multiple characters being typed, the keyboard records only one keystroke when constant pressure is detected.

Controller:

Fig. 77 Controller (Haptic feedback)

People with Parkinson's experience a wide range of symptoms and needs, even when they are at the same stage of the condition. Furthermore, their motor skills can be significantly affected by whether they are on or off medication. To accommodate these changes, the keyboard features a physical slider, enabling users to effortlessly turn on and fine-tune the vibration intensity of the switches to meet their daily preferences.

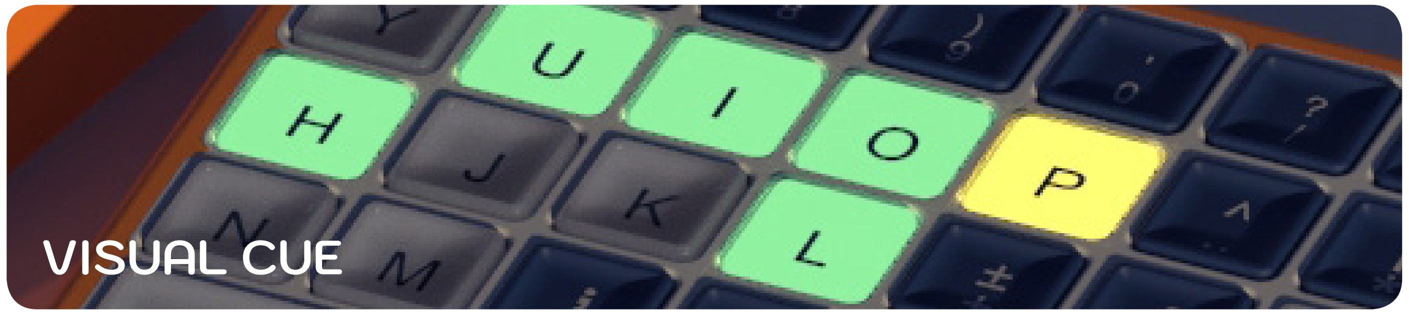
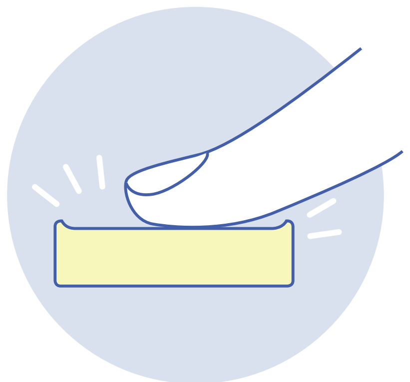


Fig. 78 Visual cue

The second feature implemented is a visual cue. When a key is pressed, it lights up in yellow to provide instant feedback. At the same time, the most likely next letters are illuminated in green, offering suggestions based on the current context. As the user continues typing, the system uses AI to refine these predictions, progressively narrowing down the highlighted keys as the word becomes more predictable. By illuminating only the most relevant keys, the system aims to reduce distractions, keep the user focused, and lower cognitive load during typing, providing a proactive prompt.



Features:

1 Key Lighting on Press: Keys light up in **yellow** when pressed, providing immediate visual feedback to the user.

2. Suggested Next Letters: Based on the selected language, the most probable letters that are likely to follow the pressed key light up in **green**, helping guide the user toward the next character.

AI

3. AI-Powered Typing: As the user types, the system uses **AI** to predict and refine the suggestions. The more the user types, the fewer keys light up, as the AI narrows down the most likely next letters, increasing typing speed and focus.

4. Spacebar Function: When a word is completed and the **spacebar** is pressed, all keys turn off, signaling the end of the current word and resetting the display for the next input.

Fig. 79 Turned on keyboard, visual cue

Controller:

Similar to the integrated haptic cue, the visual cue also features a slider to enable or disable the function and adjust the light intensity. Additionally, a switch allows users to toggle between Dutch and English, ensuring they receive accurate light prompts based on their selected language (Fig. 81).

Fig. 80 Visual cue on pressed key

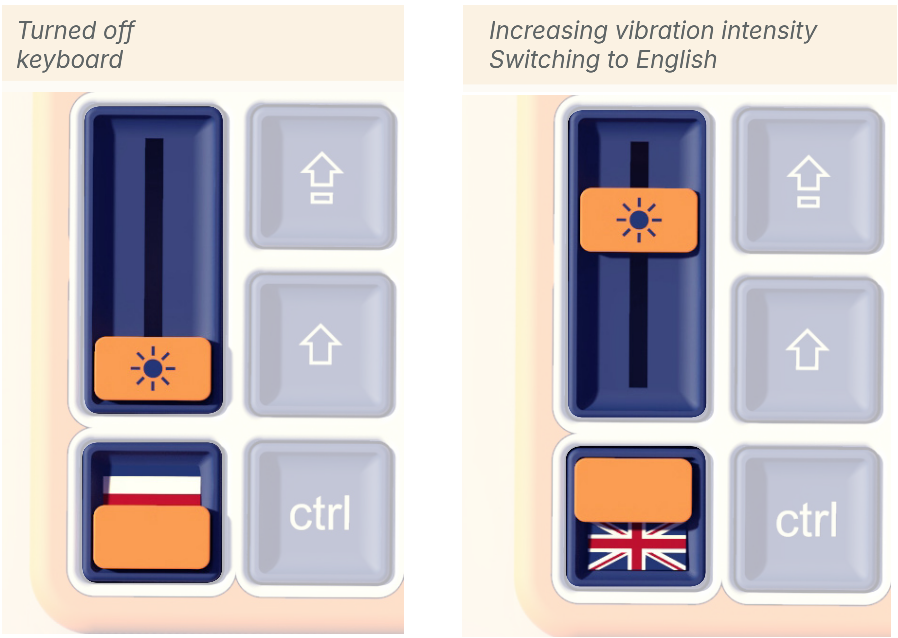


Fig. 81 Controller (Visual cue)

Switch module components:

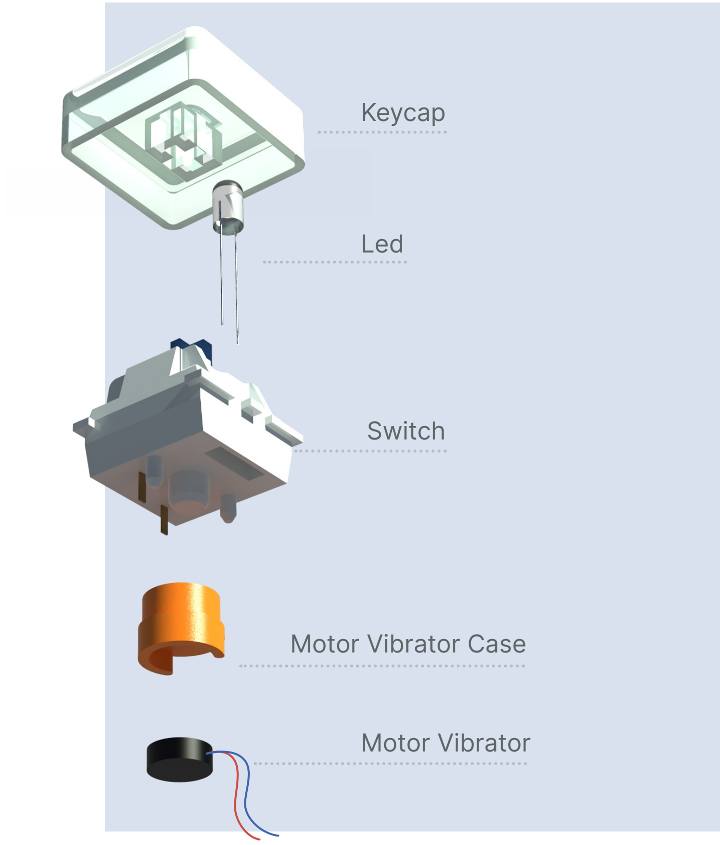


Fig. 82 Exploded view

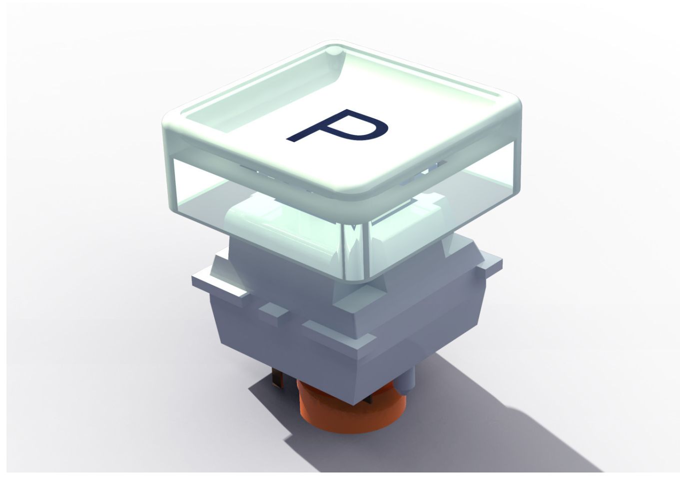


Fig. 83 Switch module

The keyboard is built using mechanical switches, which provide space for integrating LEDs, enabling the implementation of visual cues as shown in figure 82. A custom keycap has been designed specifically to address tremors, featuring a slight edge to assist users in pressing the correct key. Additionally, a dedicated component has been added to house the vibration motor for haptic feedback.
Since mechanical switches are standard components, the custom keycap and motor housing are compatible with nearly any mechanical switch available on the market.

Technical drawing:

All dimensions are in mm.

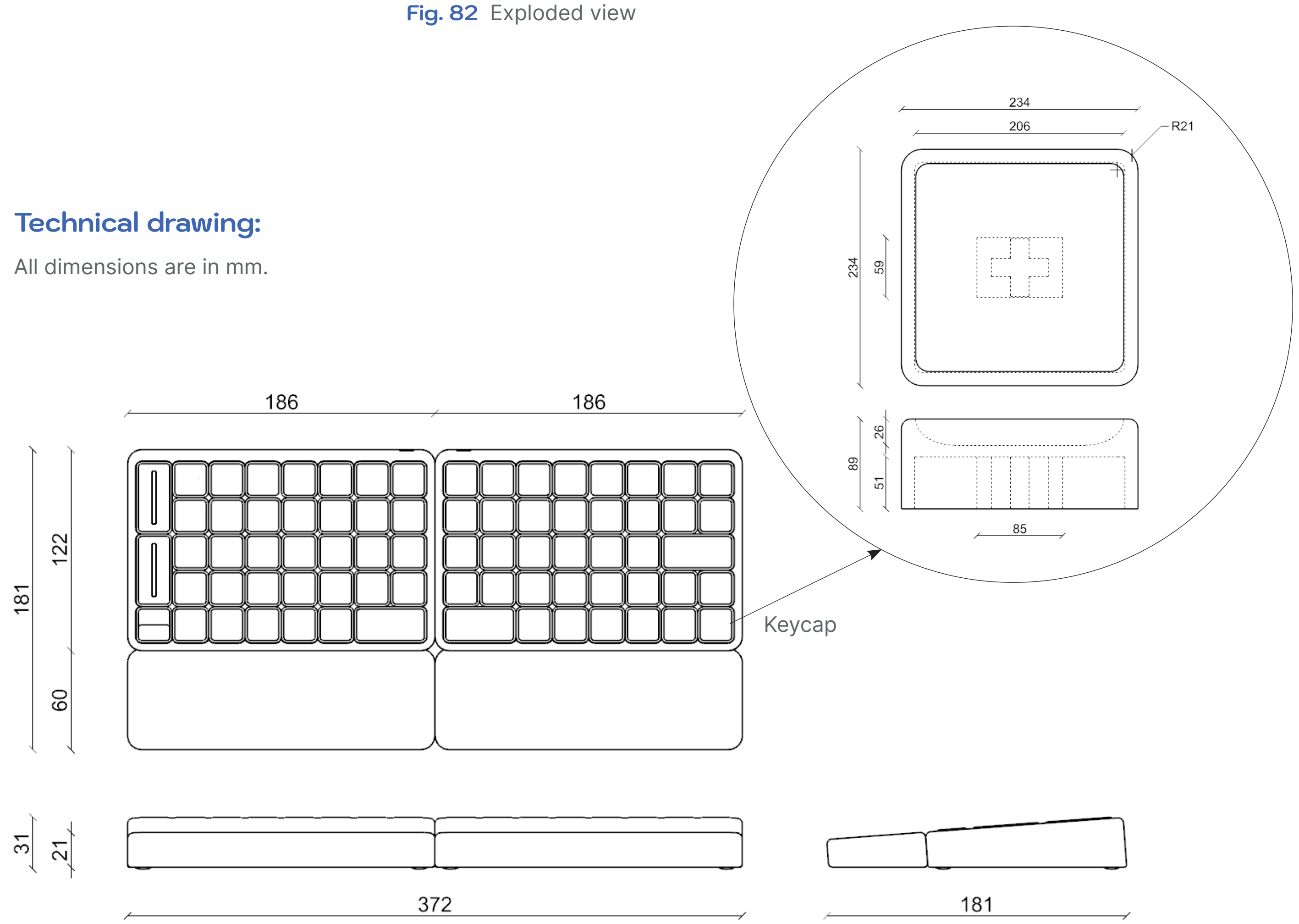


Fig. 84 Keyboard and keycap dimensions

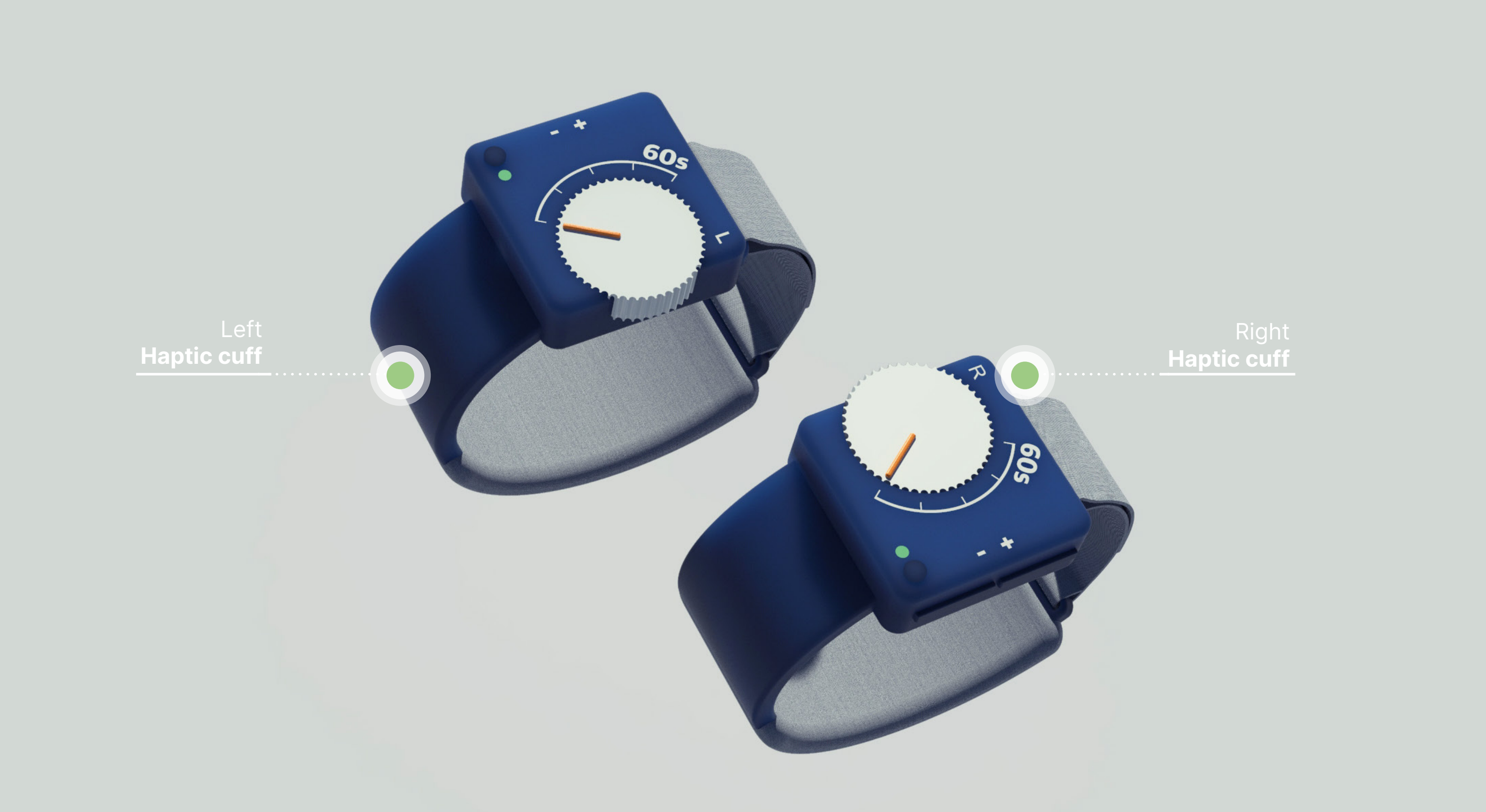
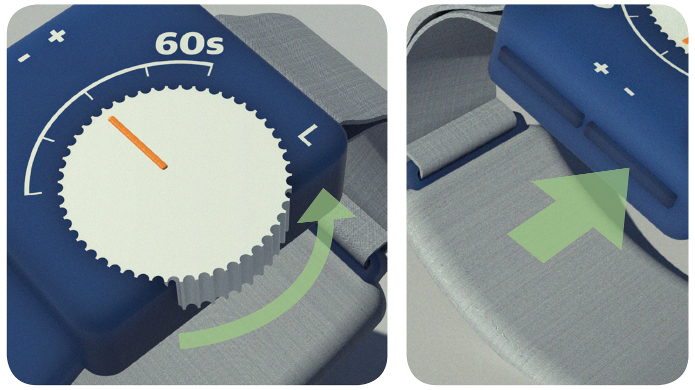


Fig. 85 Left and right cuff

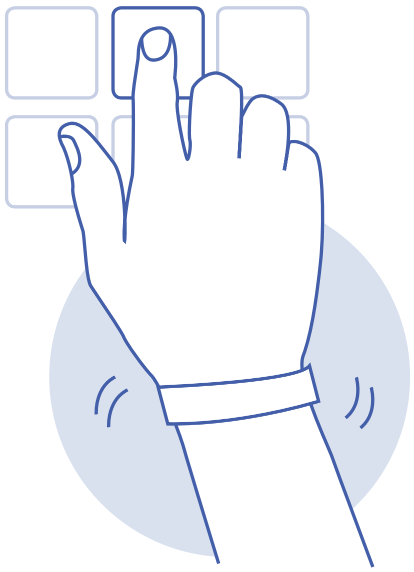
8.3 Haptic Cuffs

The keyboard is equipped with two haptic cuffs, wirelessly connected to the keyboard, which deliver tactile feedback to the user's wrists.

Each cuff is labeled with an "R" for the right and an "L" for the left to distinguish between them. These cuffs feature a controller and a soft section housing a vibration motor. The physical controllers allow users to easily adjust the settings for comfort and functionality on a daily basis.



Figs. 86 and 87 Controllers



Features and controller:

1. Vibrating Cuff
Each time a key is pressed, the cuff vibrates to provide feedback. The controller (Fig. 87) includes two buttons, marked with plus and minus symbols, allowing users to easily adjust the vibration intensity to their liking.

2. Stuck Finger Detection
If a user's finger remains on a key for too long, the cuff will gradually increase its vibration to encourage the user to lift their finger. To prevent repeated characters, the keyboard will register only one letter when continuous pressure is applied.

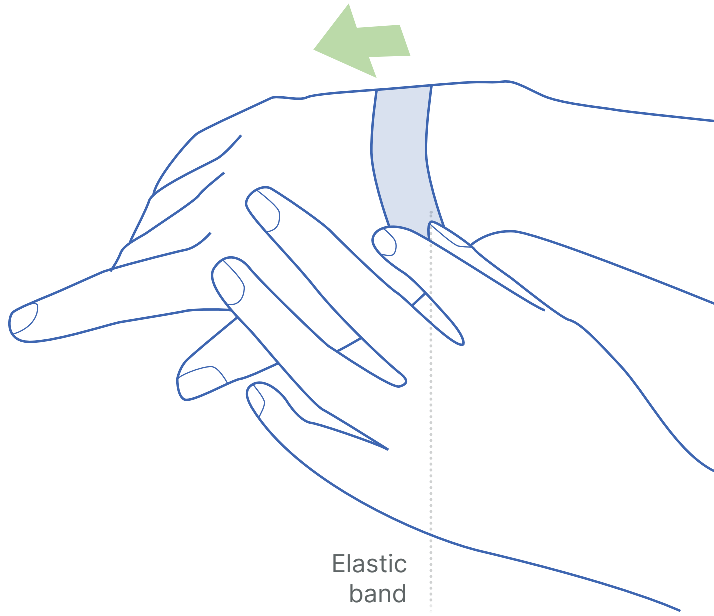
3. Freezing Prevention
If no keys are pressed for a few seconds, the cuff vibrates to prompt the user to resume typing. The controller features a dial that allows users to activate this function and adjust the time delay, with a maximum setting of 60 seconds, to suit their preferences (Fig. 86).

Fig. 88 Haptic cuff

Cuff components:

The haptic cuff consists of several key components: a housing for the electronics and controllers, a silicone band that carries the wires for the vibration motor, and a soft pouch that encloses the motor itself.

Attached to this module is an adjustable elastic band that allows users to modify the length for a comfortable fit. This elastic band, secured with Velcro, makes it easy for users to put on and take off the cuff, which is particularly important for individuals with Parkinson's who may struggle with fine motor skills.



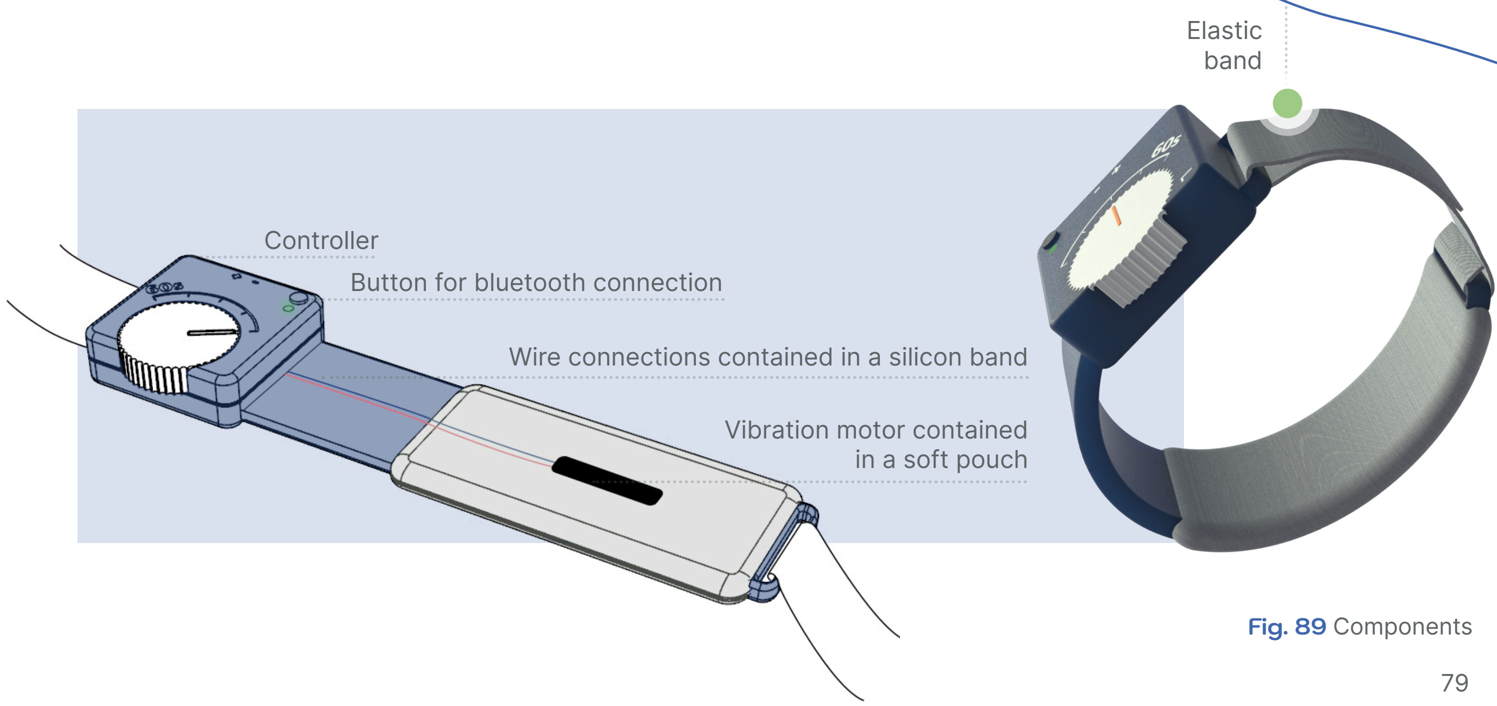


Fig. 89 Components

Adaptability:

Building on the findings from the study "A Fabric-Based Approach for Wearable Haptics" (Bianchi, 2016), which demonstrates that haptic feedback can be effectively applied to various areas of the arm including the forearm, upper arm, and wrist this research project emphasizes the importance of adaptability in its design.

With a recommendation for the next project phase to focus on user experience exploration, the development has centered on creating a highly versatile device. This device is designed to be easily adjusted and positioned on different parts of the arm, as shown in Fig. 91, providing users with the flexibility to experience haptic feedback in multiple locations. This adaptability enables a more comprehensive evaluation of how haptic feedback performs across these areas, facilitating a deeper understanding of its effectiveness. Ultimately, this approach ensures that users can tailor the device to their unique needs, resulting in a more personalized and optimized experience.

Technical drawing:

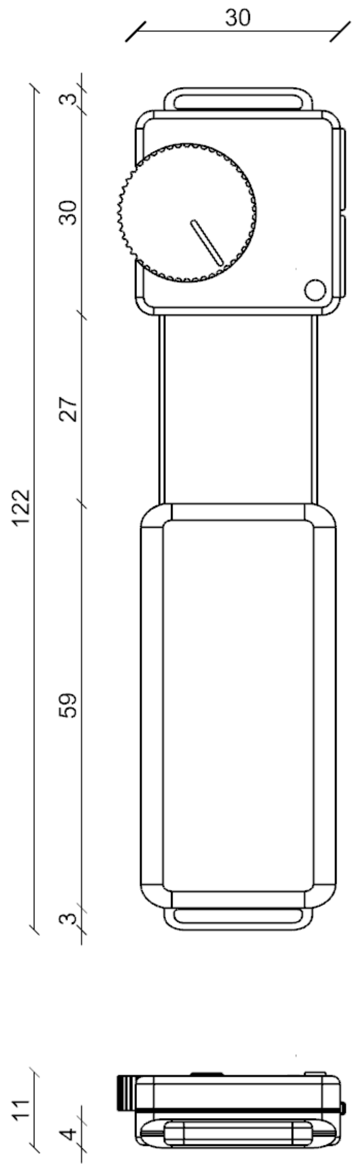


Fig. 90 Cuff dimension

Fig. 91 Cuff adaptability

8.4 Modularity and customization

Modularity is a key aspect of OnCue, as the needs of people with Parkinson's can vary greatly. The product is designed to be flexible, allowing users to purchase only the components they need, rather than a complete kit (Fig. 93).
For example, someone in the early stages of the disease who has difficulty with just one hand can decide to buy only one cuff instead of a full set. The palm rests are also optional; they attach to the keyboard via magnets and can be easily removed if not needed. Furthermore, the visual and haptic cue features are separate modules that can be added, along with their specific controllers, for those who require them. This modular design enables individuals to personalize the keyboard to meet their specific needs, purchasing only the parts that will benefit them.
Ideally, users should have the opportunity to try the product before purchasing to fully understand which features best suit their needs.
In addition to its modular design, OnCue offers both physical controls and software-based customization options, allowing users to tailor the product to their individual preferences. OnCue provides essential settings directly on the keyboard and cuff for quick, easy adjustments, while users also have access to companion software (Fig. 92), which can be downloaded to their computer for more advanced customization. The most frequently used controls

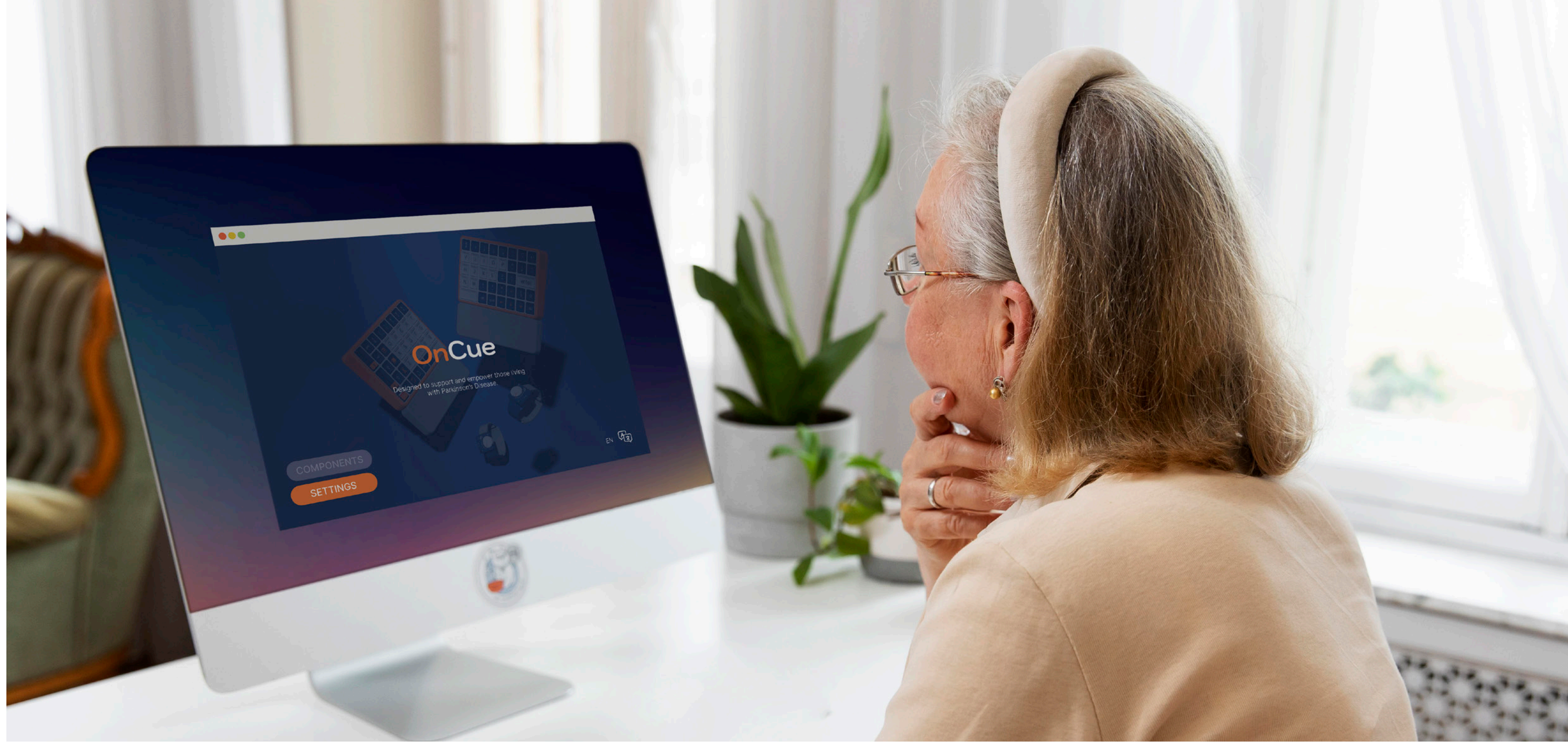


Fig. 92 OnCue software

are available physically for everyday use, while the software offers a deeper level of personalization. For example, the cuff allows users to adjust vibration intensity, while the software enables fine-tuning of vibration patterns, including the number and duration of vibrations during a freeze. All available customization options and explanations are displayed in figures 94-107.

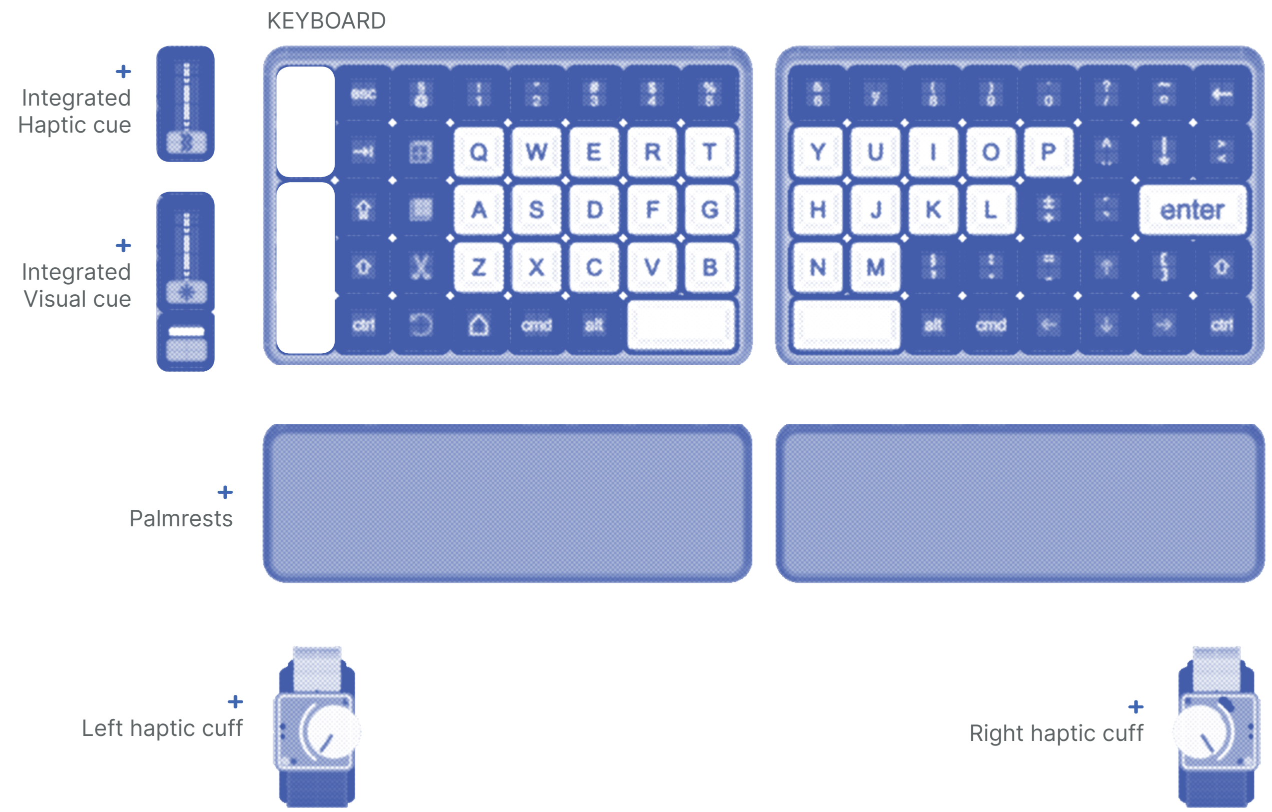


Fig. 93 OnCue components

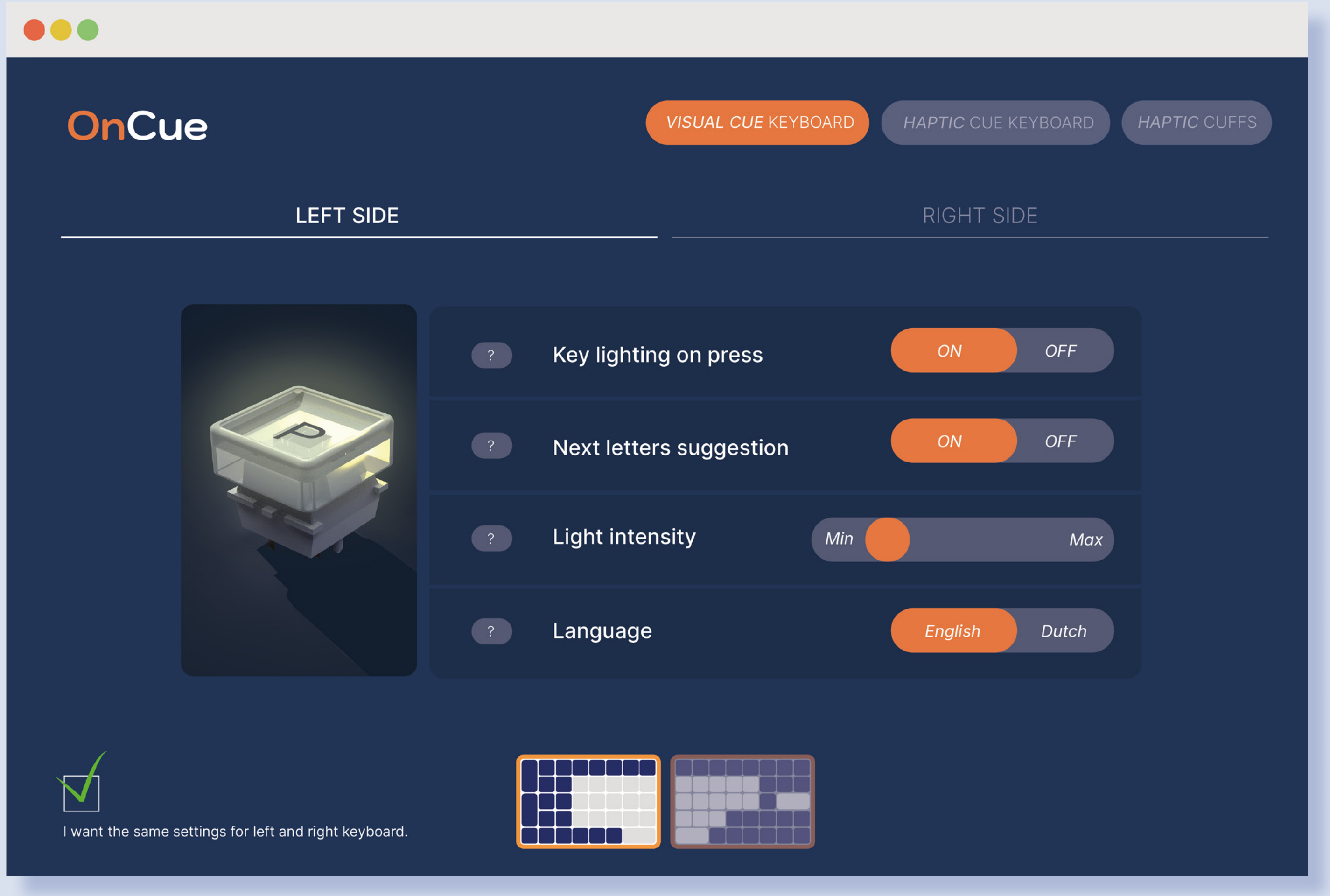


Fig. 94 Visual cue settings

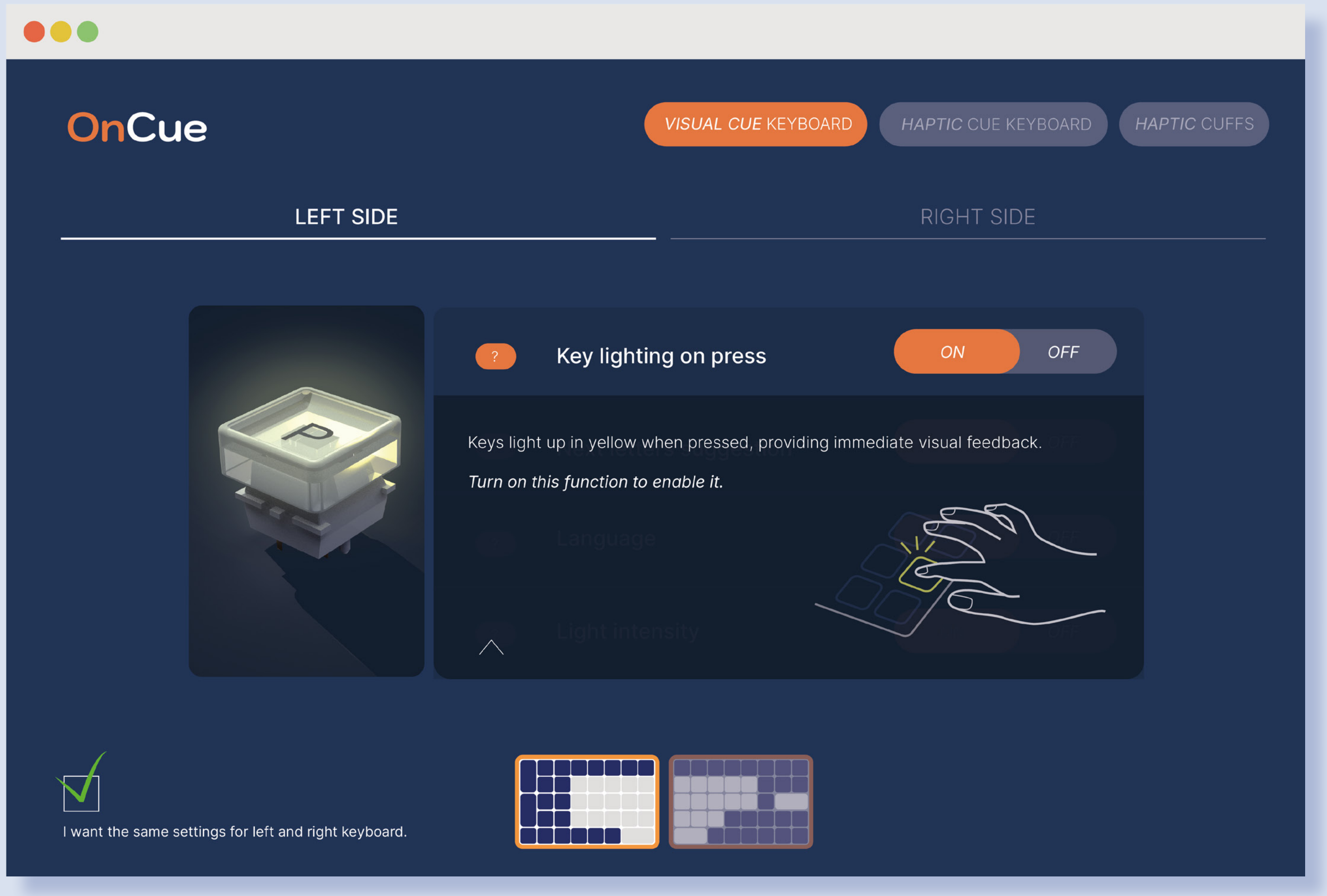


Fig. 95 Visual cue, Key light on press

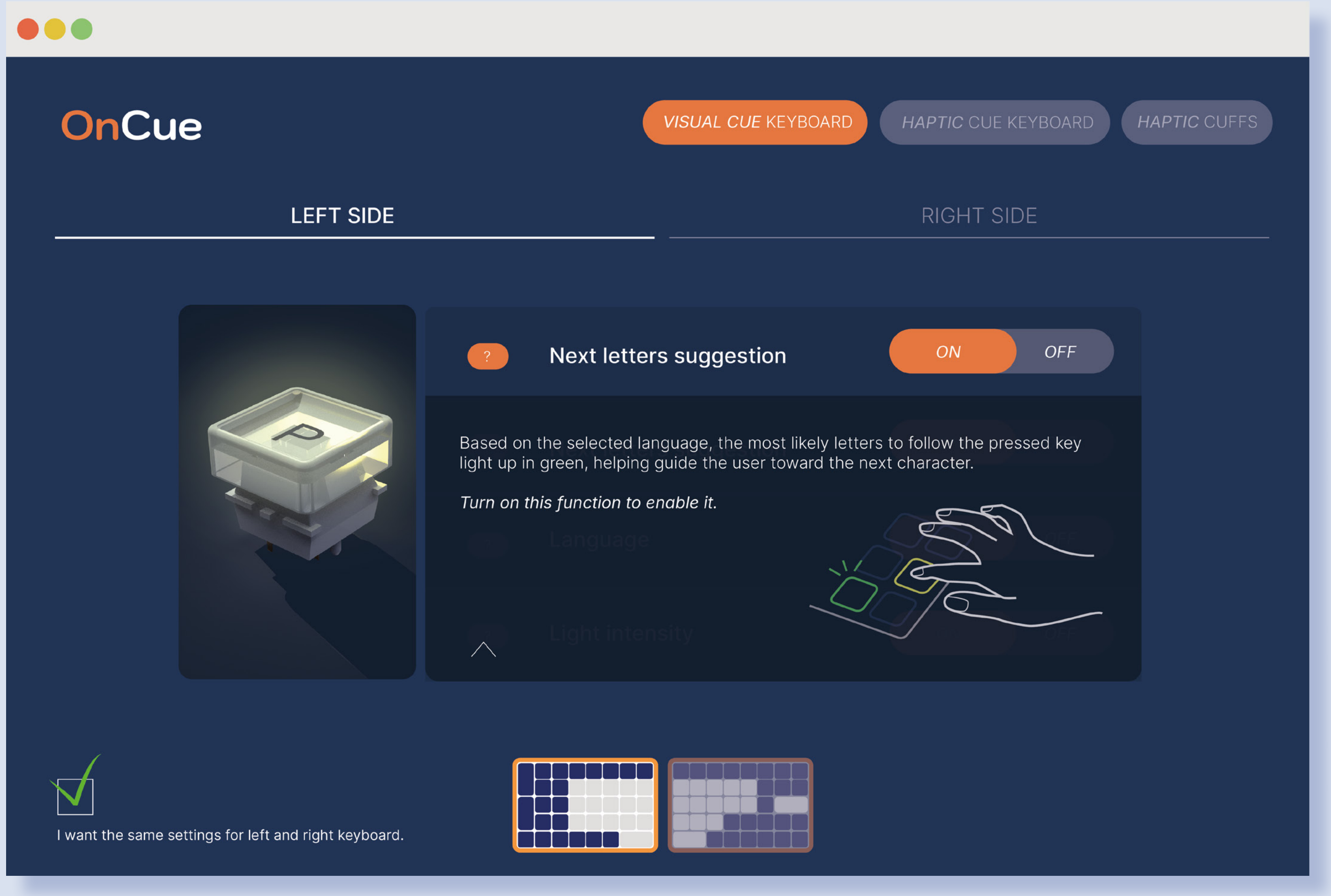


Fig. 96 Visual cue, Next letters suggestion

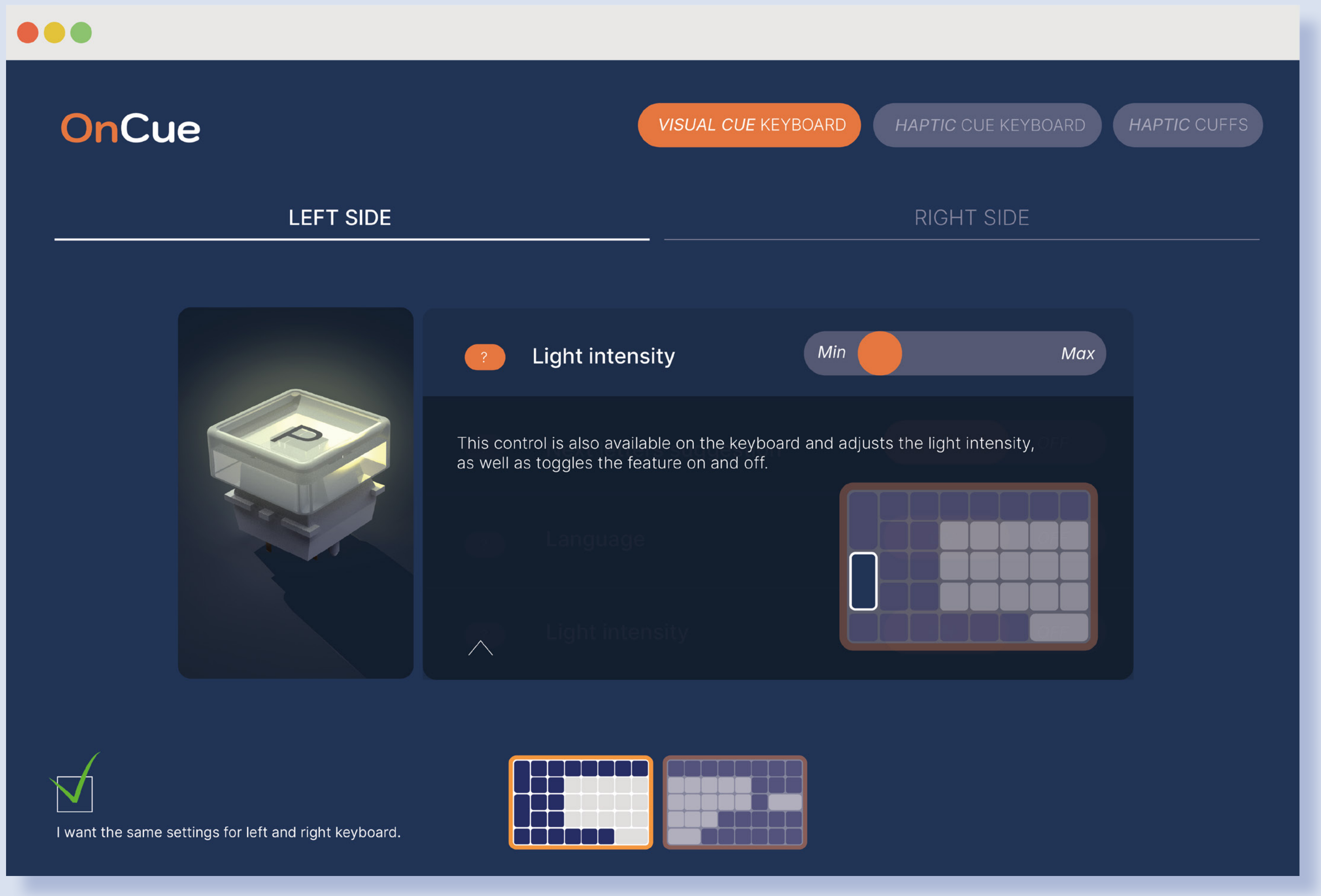


Fig. 97 Visual cue, Light intensity

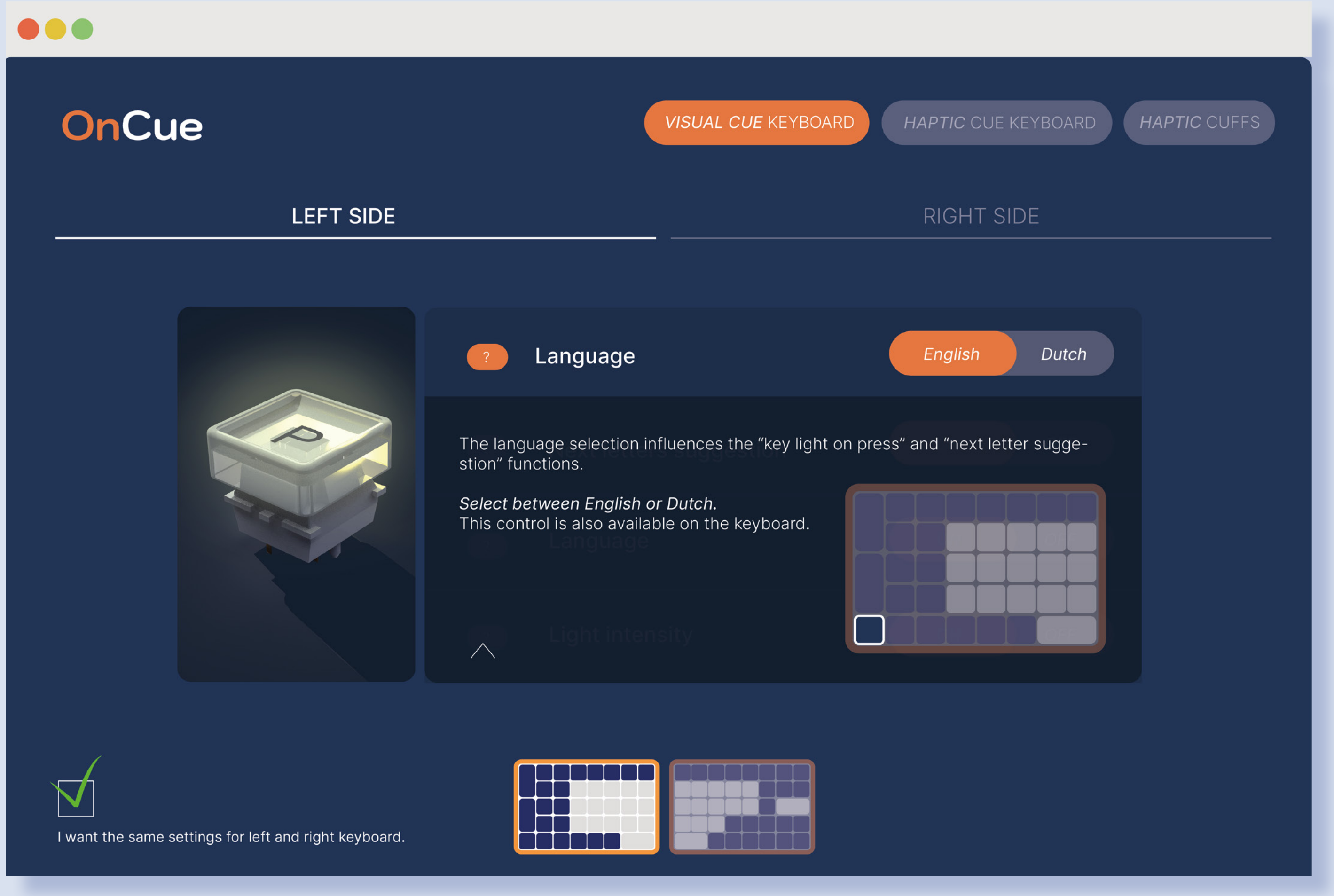


Fig. 98 Visual cue, Languagelciunt etur solupti

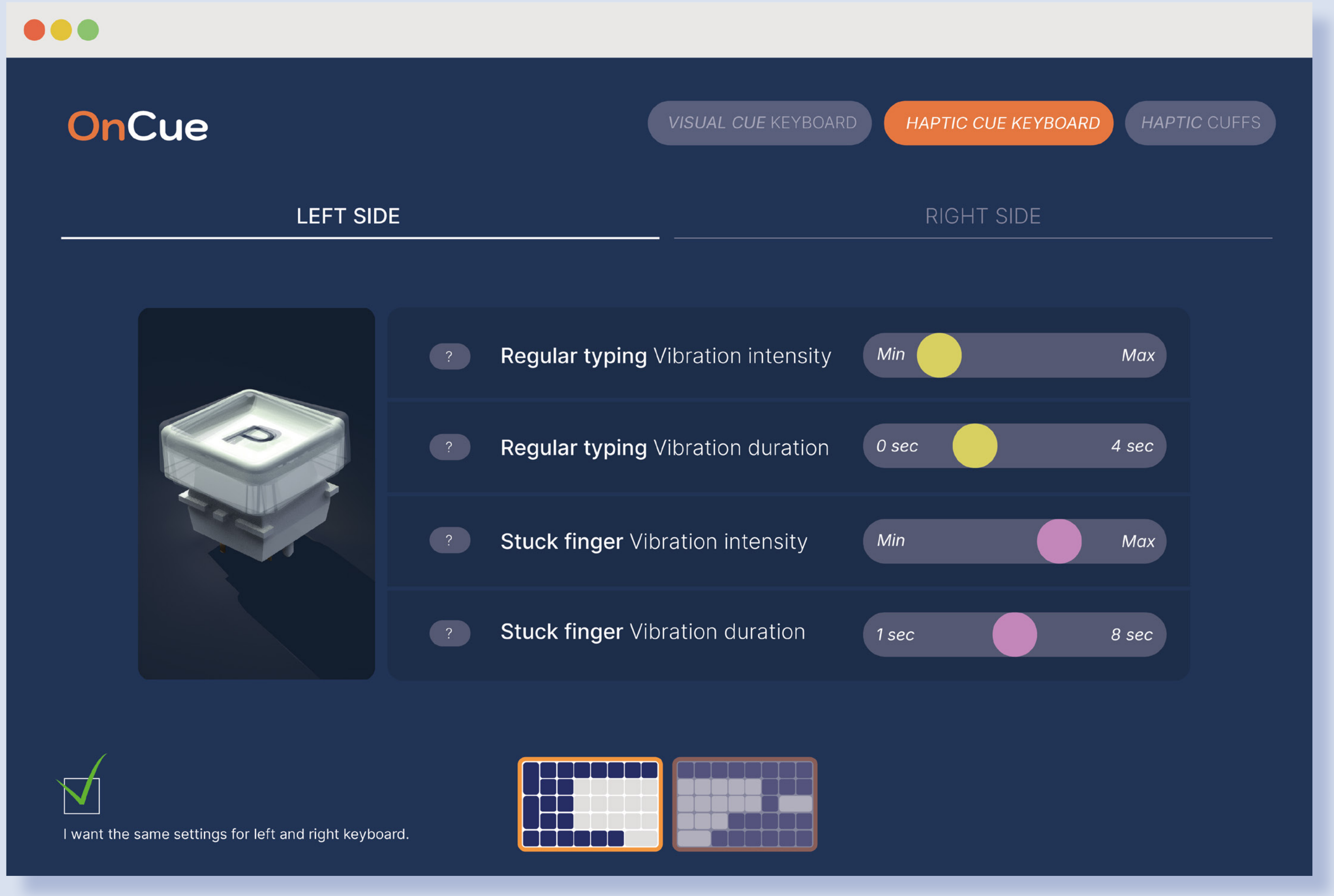


Fig. 99 Haptic cue settings

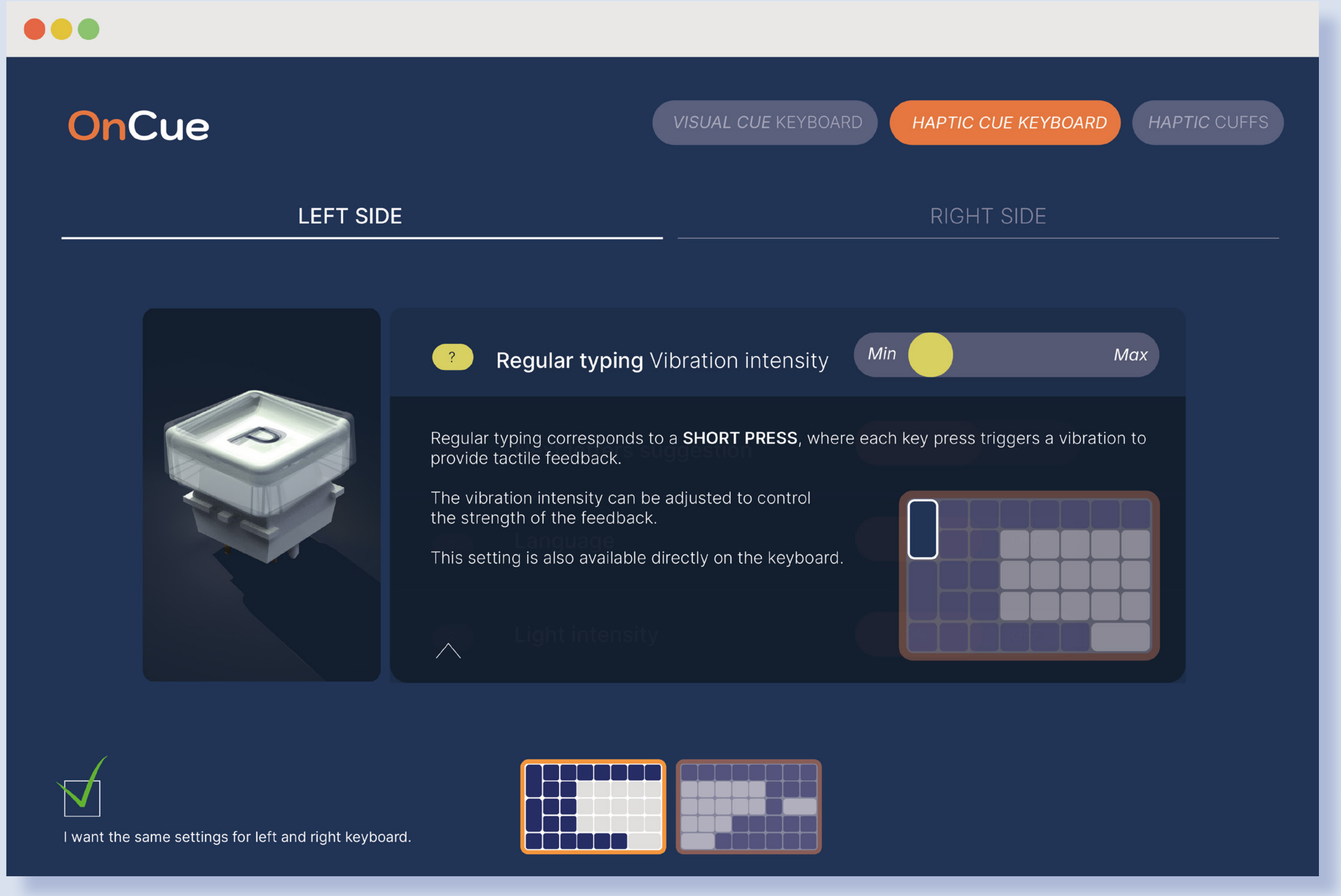


Fig. 100 Haptic cue, Regular typing (vibration)

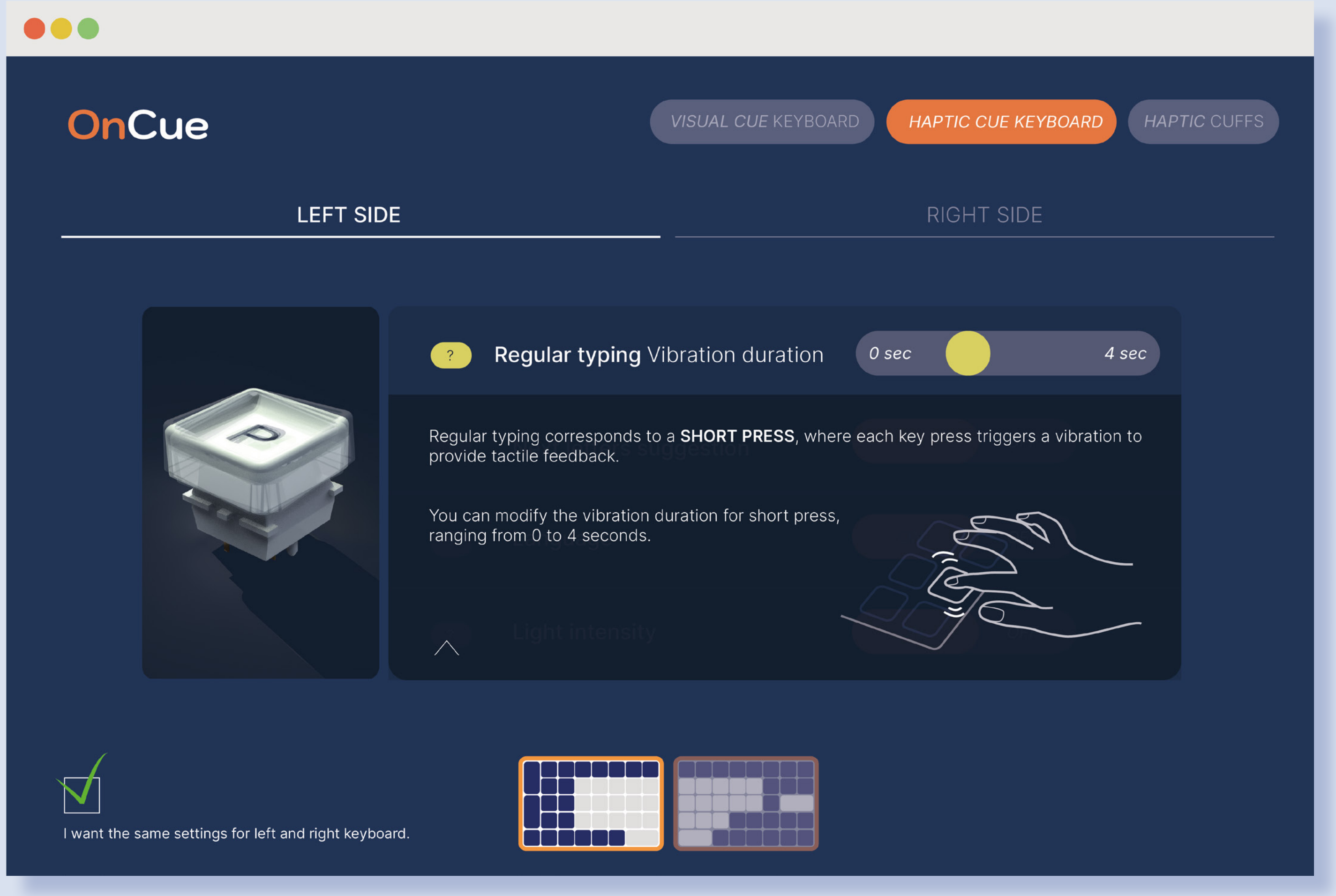


Fig. 101 Haptic cue, Regular typing (duration)

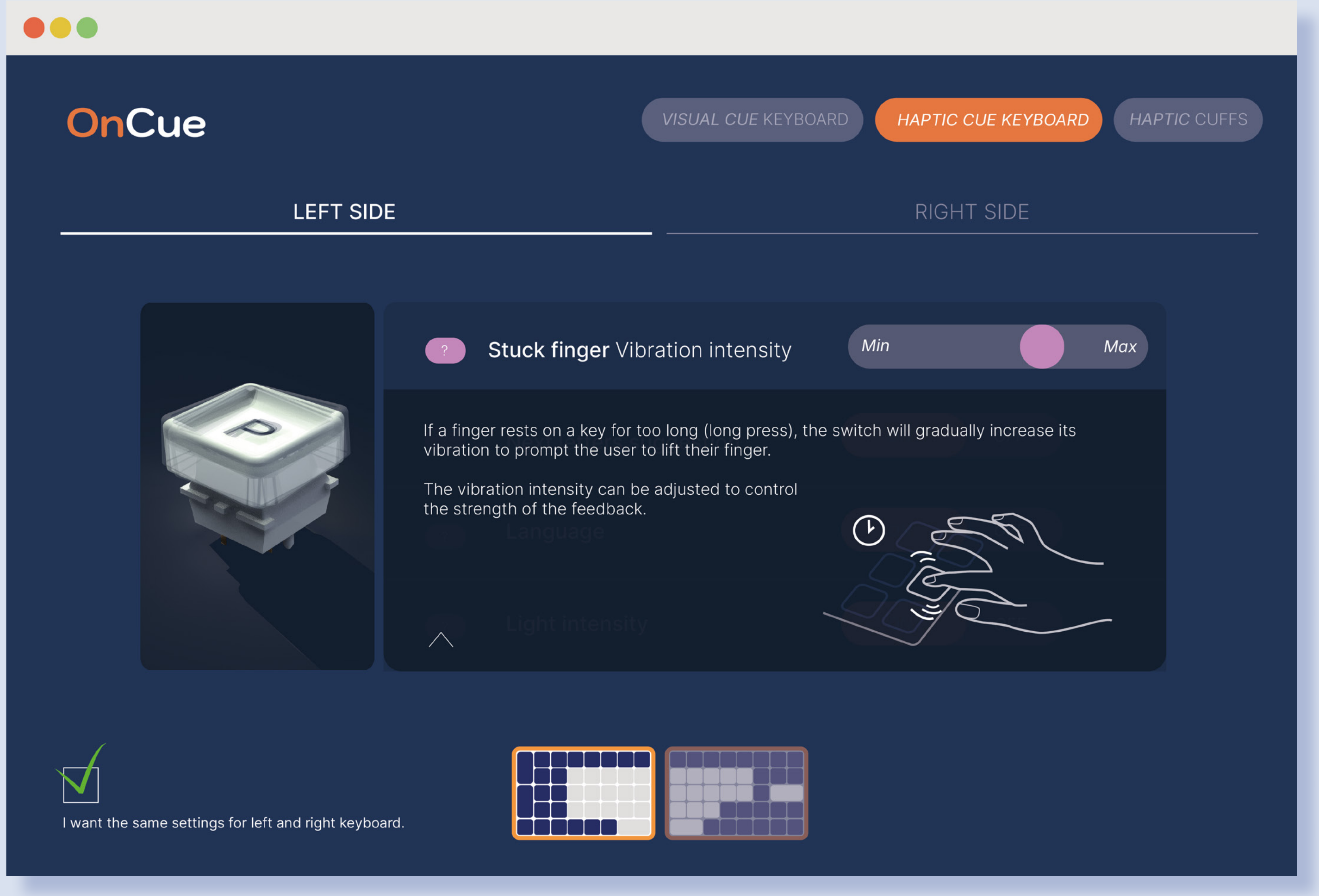


Fig. 102 Haptic cue, Stuck finger (intensity)

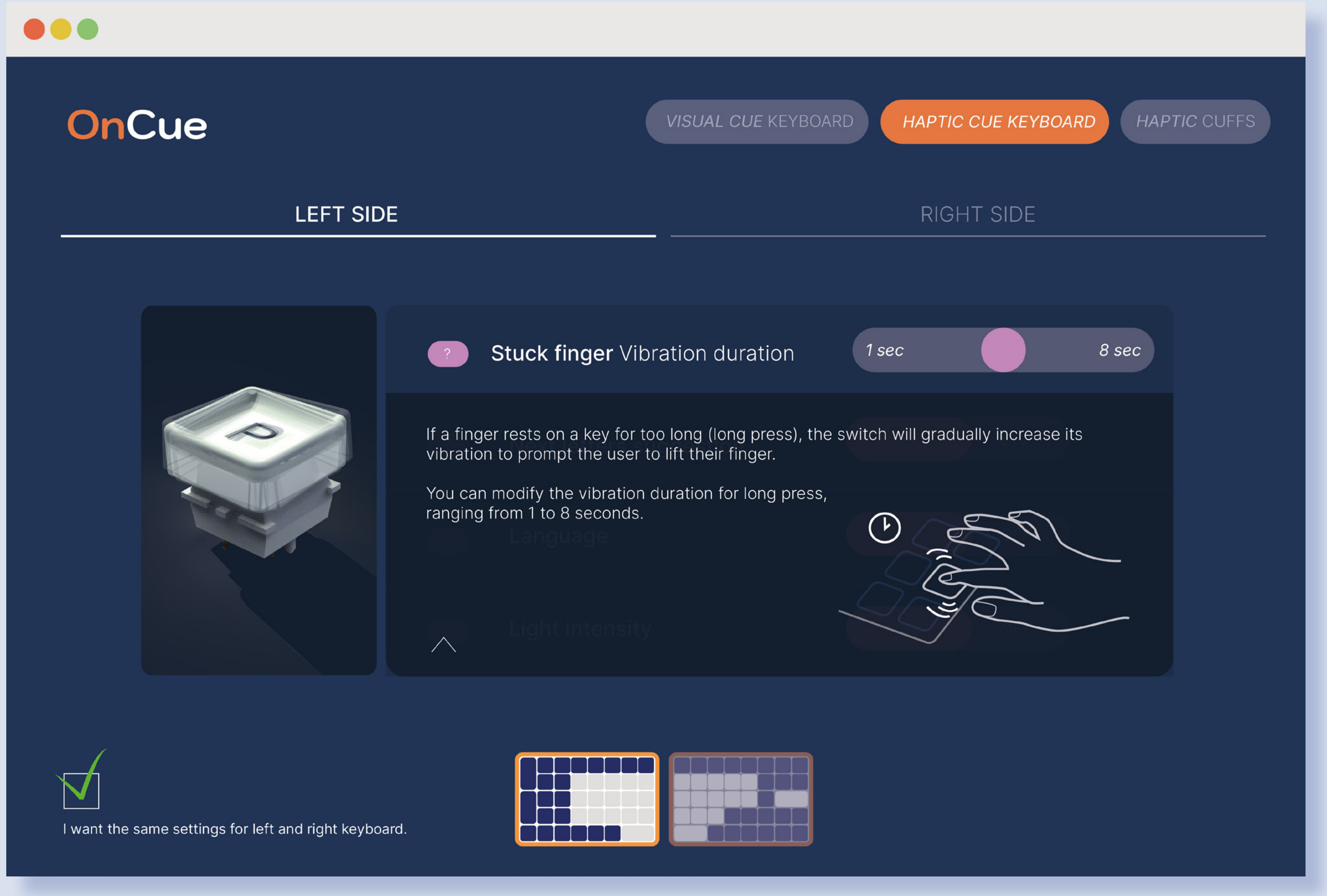


Fig. 103 Haptic cue, Stuck finger (duration)

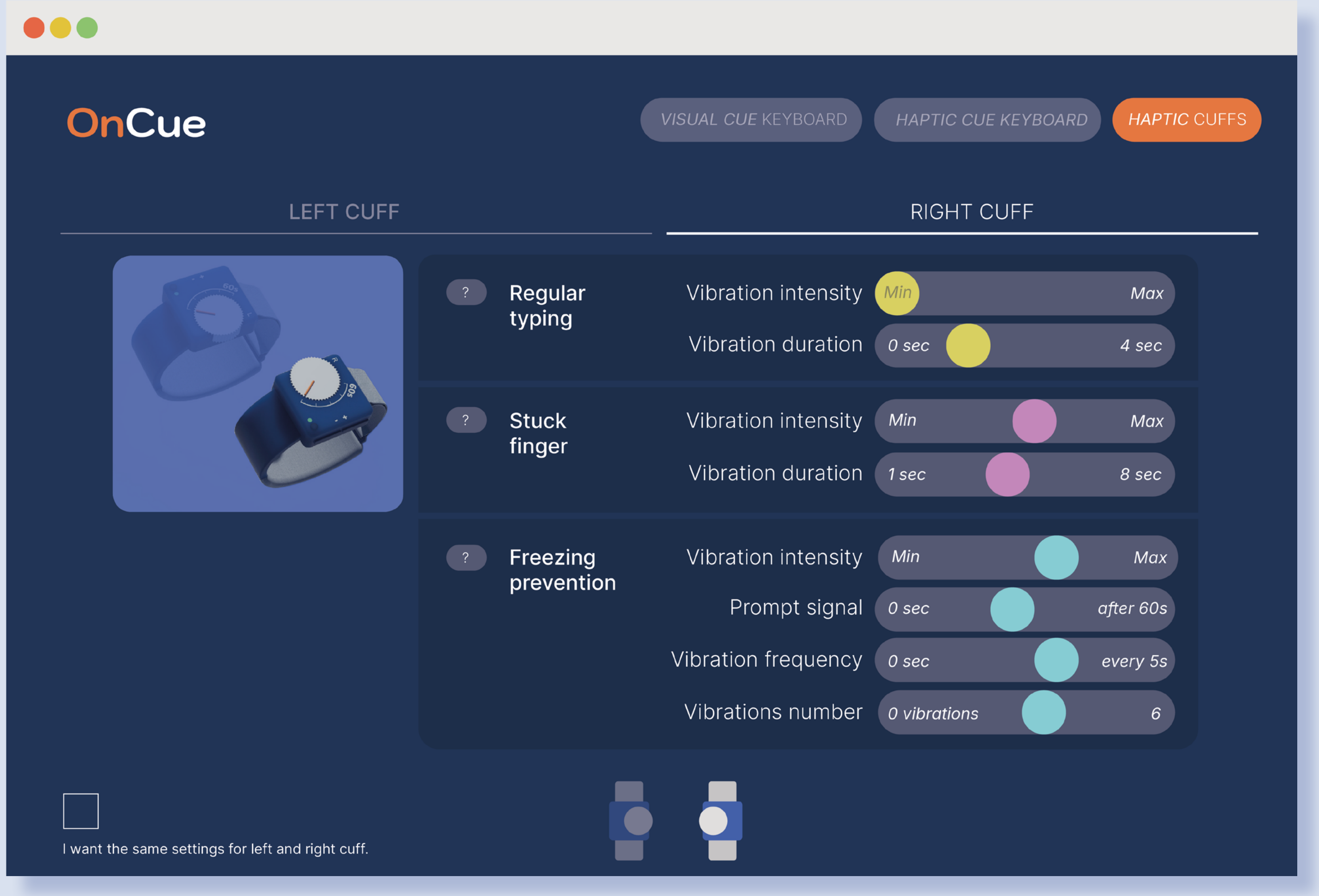


Fig. 104 Haptic cuff settings

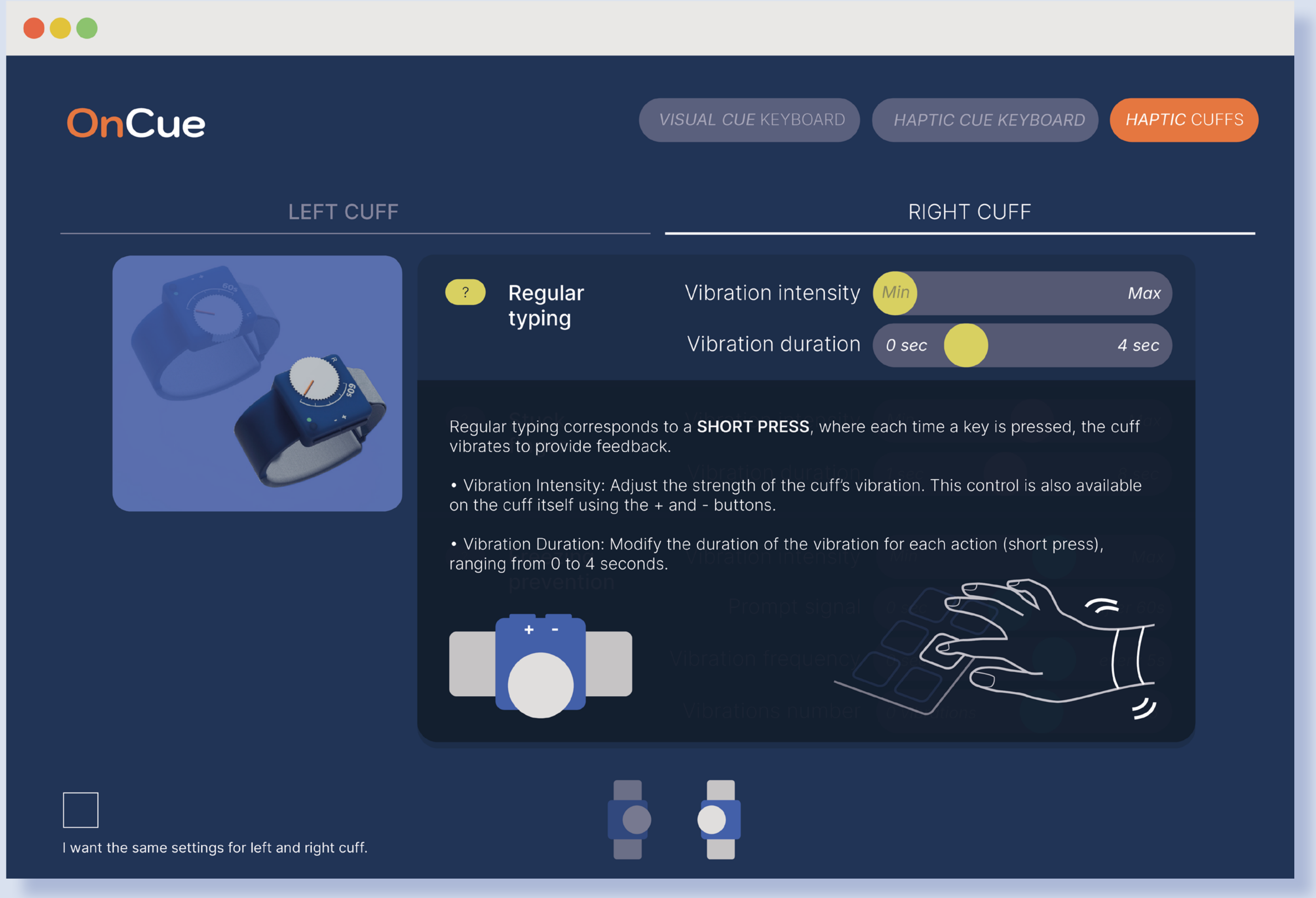


Fig. 105 Haptic cuff, Regular typing

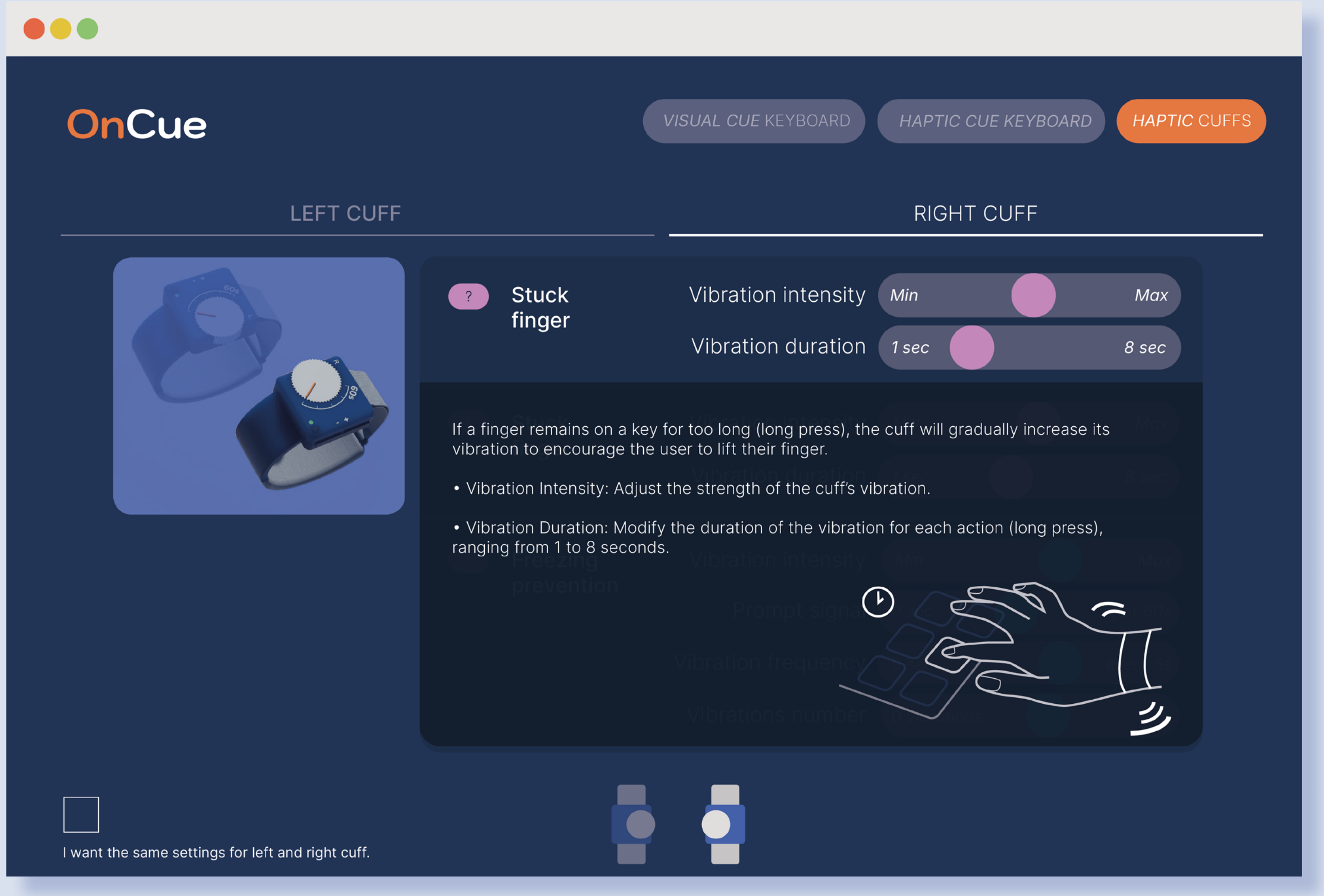


Fig. 106 Haptic cuff, Stuck finger

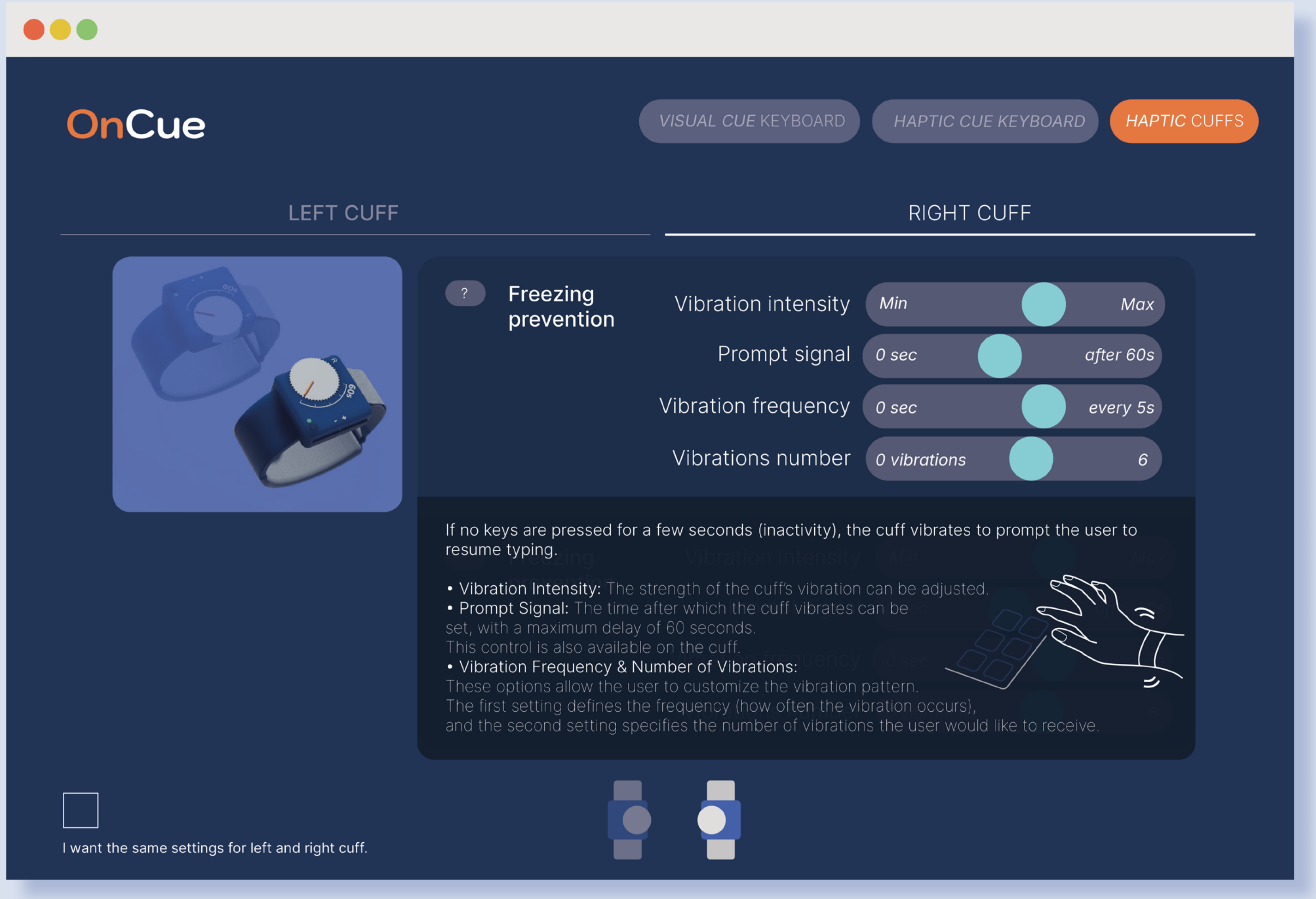


Fig. 107 Haptic cuff, Freezing prevention

Fig. 108 Final aesthetics prototype

Fig. 109 Final prototype in a lifestyle setting

9. Discussion

9.1 Evaluation

This chapter explores the project's evaluation, where the concept is critically analyzed component by component, highlighting potential directions for future enhancements. The aim is to delineate the next steps required for further development.

Fig. 110 provides a product evaluation based on the predefined requirements. Each requirement has been assessed to determine whether it has been met, with supporting explanations.

	Requirements	Evaluation
1	OnCue *must* reduce the influence of bradykinesia in computer interaction providing visual/auditory/ somatosensory cue empowering individuals and reducing their feeling of frustration.	This requirement is the most crucial for the success of the project. Initial testing has shown promising results, indicating that the solution may effectively address the intended challenges. However, additional rounds of testing across different user groups and conditions are necessary to thoroughly evaluate its effectiveness, reliability, and long-term performance.
2	The keyboard *must* be designed to be fully operable with one hand if necessary.	✔ The split keyboard features a compact grid layout, optimizing space while maintaining functionality. Although it consists of two detachable parts, the halves can be positioned close together for one-handed use.
3	The keyboard *must* be compact (size 65%, 68- keys).	✔ The keyboard follows a 65% layout, offering a compact and efficient design.
4	The keyboard *must* have adjustable amplitude allowing people to maintain a natural and unforced posture.	✔ The keyboard is split into two halves, allowing the user to position each half as they prefer, promoting a natural posture and customizable spacing.
5	The keyboard *must* have clicky switches which provide a tactile bump and an audible click.	✔ This requirement has been met, as the keyboard consists of mechanical clicky switches
6	The keyboard *must* be designed to accommodate users with tremors.	The proposed design draws inspiration from the keyguards currently sold to address this issue. In theory, it can be stated that this requirement has been achieved, but further testing is necessary to properly evaluate its effectiveness.
7	OnCue *must* be be modular and customizable.	✔ This requirement has been met by designing OnCue as a modular system, allowing users to purchase only the components they need to address their specific requirements. Additionally, physical controllers and the OnCue software provide extensive customization options for various features, ensuring the device can be tailored to individual user preferences.
8	The keyboard *should* have keys of different colors.	✔ This requirement has been met, as the lettered switches are made of transparent plastic, while the others are blue to clearly differentiate between them.

Fig. 110 Requirements and evaluations

KEYBOARD

Keyboard's ergonomics

Split keyboard with orthloinear layout.

Fig. 111 Split ortholinear keyboard

Advantages

The research suggests that cueing techniques alone may not fully address the complexities of bradykinesia, which manifests through a range of symptoms. However, an ergonomic keyboard design could substantially enhance the overall user experience. A **split keyboard** encourages a more natural posture, reducing strain on the hands and arms, while the **ortholinear key layout** may reduce finger fatigue by simplifying finger movements. The **compact** 65% layout further benefits individuals with Parkinson's disease, as bradykinesia results in reduced movement amplitude, making a smaller layout more suitable.

Additionally, integrating a keyguard concept directly into the product's structure, along with **custom keycaps** featuring raised edges, could significantly reduce errors caused by tremors. This design could provide better control compared to traditional flat keyboards with external keyguards. The inclusion of **shortcut keys** could further minimize frustration by reducing the need for simultaneous key presses, enhancing ease of use for individuals with motor challenges.

The **keyboard's modular design** offers flexibility, with palm rests designed as swappable components that can be easily added or removed based on user preference. This allows users to customize their setup for maximum comfort and convenience. Utilizing standard mechanical switches that allow users to swap keycaps of varying heights to suit their preferences. Moreover, **mechanical "clicky" switches** provide durability and high performance, delivering both tactile and audible feedback, features highly regarded in online Parkinson's communities. Unlike membrane switches, mechanical switches do not require full keypresses to register, which can reduce the effort needed for typing. Mechanical keyboards can feature either soldered or hot-swappable switches, allowing for easy customization or replacement based on user preference. If users prefer not to use clicky switches, which offer both a tactile bump and an audible click, they can easily switch to linear switches (silent) or tactile switches (tactile bump without a loud click). This flexibility allows users to select the type of switch that best suits their needs and preferences.

Limitations

Every individual has unique preferences when it comes to product use, and the thickness of the keyboard and keys may not suit everyone's tastes. Additionally, using a separate keyboard from a laptop can be inconvenient, particularly for those who prioritize portability.

While data supports the ergonomic benefits of certain design choices—such as the split keyboard and compact 65% layout for addressing bradykinesia—some users may prefer alternative layouts or configurations. For instance, they may want different shortcut key setups tailored to their specific workflows. Moreover, some users might prefer a thinner keyboard without the integrated keyguard, as the choice of mechanical switches impacts the overall thickness of the product.

Every component and feature of the design was thoughtfully selected based on thorough research and consideration. However, certain choices, such as the preference for an ortholinear layout over a staggered one, remain assumptions. There is no conclusive ergonomic data proving that the ortholinear layout is superior. These design assumptions will need to be validated and refined through further testing with the target group to ensure they truly meet users' needs and enhance their quality of life.

Future steps and opportunities

•The next step is to test a full-size working prototype with the target group to gather additional feedback and assess how users experience and validate the design decisions made. This step will focus on evaluating the keyboard's ergonomics, components, and features.

•The keyboard's modularity offers significant opportunities. The use of standard mechanical switches allows for easy customization. Currently, the prototypes used to validate the concepts are hand-wired, but designing a printed circuit board (PCB) would enable easier switch replacements. For those who prefer a quieter typing experience, clicky switches can be swapped for silent alternatives, further enhancing user flexibility. This modularity ensures the keyboard can be easily tailored to meet individual needs and preferences.

• If feedback indicates a preference for a thinner keyboard, it is possible to maintain the use of mechanical switches while redesigning the keyboard's structure and replacing standard switches with low-profile ones, which are 30%-40% shorter than regular mechanical switches (Gateron Switch, 2023), thereby making the entire keyboard thinner.

Fig. 112 Regular and low-profile switches

Feature 1: Haptic feedback in the Keyboard

The keyboard features integrated haptic feedback in its switches.

Fig. 113 Haptic cue

Advantages

The integrated haptic feedback has shown promising results during testing. The vibrations applied to the fingertips appear to aid users in completing key presses, making it an effective countermeasure to bradykinesia. Since the feedback system is embedded directly into the keyboard, users do not need to wear additional devices or rely on external components. The onboard controller offers easy customization of key functionalities, making the system user-friendly and intuitive. Additionally, the OnCue software provides advanced personalization options, which are especially useful in meeting the diverse needs of different users. The design's feasibility has been demonstrated through successful testing with a working prototype. Furthermore, a parallel study by Stanford researcher Peter Tass has developed a vibrating glove designed to alleviate Parkinson's symptoms, such as tremors, stiffness, and bradykinesia, by desynchronizing abnormal neuron activity. The glove delivers vibratory bursts to the fingertips, resetting abnormal brain patterns. Ongoing clinical trials are exploring this noninvasive treatment alternative (Stanford Medicine, 2024). This parallel research, which also targets the fingertips, reinforces the potential of haptic feedback as a promising approach for managing motor symptoms.

Limitations

The haptic feedback in the switches is reactive rather than proactive, which is a notable limitation, as it does not include a feature to prevent freezing episodes—an important factor in fully addressing all symptoms of bradykinesia. Additionally, the sound emitted by the vibration motor may be bothersome, potentially disturbing others nearby and causing discomfort for the people with Parkinson's.

Future steps and opportunities

• Testing full-size working prototype

• Compared to the vibration motor used in the feature prototypes tested by the focus group, the final concept allows users to adjust the vibration intensity, reducing the feedback sound as needed. However, increasing the intensity with a standard motor also raises the noise level. To improve usability in public settings, it's essential that the motor remains inaudible, preventing embarrassment and avoiding disturbance to others. Further research into quieter haptic feedback technologies is needed. Potential solutions include low-noise motors, sound-dampening materials, or piezoelectric systems, which offer quieter vibrations. Since users haven't fully evaluated how the motor's sound impacts their experience, additional testing is necessary. A valuable feature could be allowing users to switch to silent mode in public and activate stronger feedback at home or in private settings.

Feature 2: Visual cue in the Keyboard

The keyboard features integrated visual cue in its switches.

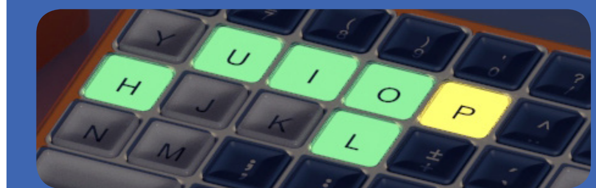


Fig. 114 Visual cue

Advantages

The visual cue offers a practical alternative to haptic feedback, providing a hands-free solution that enhances workflow efficiency. Feedback from two focus groups indicated interest in this feature, with participants suggesting it could be particularly useful for those who do not type without looking at the keyboard. By incorporating artificial intelligence to predict the words users may type, this feature has the potential to significantly improve its effectiveness. Since it delivers proactive feedback, it is especially beneficial for managing bradykinesia by offering visual prompts that encourage smoother transitions to the next action.

The system's onboard controller allows for simple and intuitive customization of key functionalities such as the language selection, ensuring a user-friendly experience. In addition, the OnCue software provides advanced personalization options to suit individual preferences. The feasibility of this design (without AI implementation) has already been demonstrated with a working prototype.

Limitations

This feature has not yet been tested on a full keyboard with AI implementation, so we currently lack data on its overall effectiveness.

Additionally, several users mentioned that they type without looking at the keyboard, making this feature less useful for them. However, it's possible that peripheral vision could still detect the illuminated keys while typing, providing some benefit.

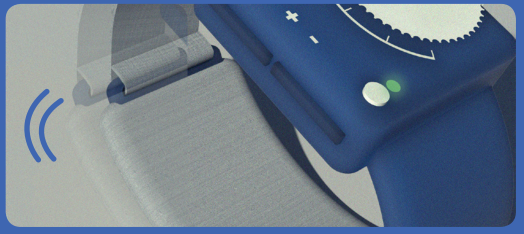
If the predictive technology proves unreliable in accurately forecasting the next word, it could lead to confusion rather than assistance, resulting in an unintended outcome for this feature.

Future steps and opportunities

• Testing full-size working prototype

• Implement artificial intelligence (AI) to enhance the system's predictive capabilities and improve overall user experience.

• Currently, the latest keyboard prototype is hand-wired, but designing a printed circuit board (PCB) with integrated LEDs would be the next step to incorporate this feature and test it with users.

CUFFS	Advantages	Limitations	Future steps and opportunities
Cuff's ergonomics Wearable cuff  **Fig. 115** OnCue Cuff	The haptic cuff features a compact design and is easily adjustable to different parts of the arm, thanks to its stretchable band, allowing users to experience haptic feedback from various body positions. The controls are simple and user-friendly, making the cuff easy to operate. It can be discreetly worn under clothing, as its compact size prevents it from appearing bulky. Additionally, its design resembles a sports accessory, allowing it to blend in more naturally. This is particularly important, as early research revealed that users prefer cueing devices that are not highly visible to others.	People need to wear the device on their body, which may be less favorable for some users. Additionally, for those who are accustomed to wearing a watch, it would be uncomfortable to wear both.	• The next step is to test a working prototype with a full keyboard on the target group to gather feedback and evaluate how users experience and validate the design decisions made. This phase will focus on assessing both the cuff's ergonomics and its features. • Another future consideration is exploring whether this functionality could be integrated into an existing smartwatch and evaluating how users would perceive this option.
Feature: **Haptic cue in cuff** The cuffs features integrated haptic feedback.  **Fig. 116** Haptic cue	The focus group provided promising feedback, with participants reporting that the haptic cuff evoked positive feelings such as relaxation and calm. This is significant, especially considering that frustration is typically the dominant emotion when using a regular keyboard. The product offers three distinct features: vibration during normal typing (short press), vibration when a finger is stuck (long press), and freezing prevention, which provides proactive feedback without requiring user action—particularly beneficial for addressing freezing episodes caused by bradykinesia. Additionally, the working prototype demonstrates that the concept is feasible.	The current vibration motor can be too loud for some users. This is particularly important, as users do not want to disturb others around them. Another limitation is that the current setup only provides feedback to the cuff on the corresponding side of the keyboard (left cuff for the left side, right cuff for the right side). As a result, if a user presses keys on the left while wearing the cuff on the right, they will not receive feedback. Moreover, at the moment, the product offers three key features: vibration feedback for short press, long press, and inactivity, which helps during freezing episodes. However, there is currently no functionality to detect bradykinesia by analyzing movement patterns.	• Test the working prototype over an extended period of time. • Further research is needed to identify a quieter and more efficient motor and to understand how it is perceived by users—similar to the research required for the keyboard's enhanced haptic feedback. It's essential to ensure that the vibration motor for the cuff has the appropriate dimensions and thickness to be housed in a soft, comfortable pouch, making it easy to wear while maintaining comfort. • Additional research is needed to implement the ability to customize cuff-to-keyboard association. For example, if a person prefers to use only the left cuff with the full keyboard, they should be able to easily associate the cuff with both the left and right sides of the keyboard. Similarly, if the person later wishes to use both cuffs—connecting the left cuff to the left side and the right cuff to the right side of the keyboard for a more natural, comfortable posture—they should be able to do so without difficulty. • Additional research is needed to explore how wrist sensors can detect Parkinson's movement patterns, including bradykinesia and tremors, to generate proactive cues that are not solely based on time. Incorporating this feature could significantly enhance the product's ability to address a wider range of Parkinson's symptoms, providing more comprehensive support for users. • Another key opportunity is to simplify OnCue by removing the need for its dedicated keyboard, while maintaining cuffs that can operate independently. This would allow seamless integration with existing keyboards on various laptops and computers. It's important to assess whether an ergonomically optimized keyboard could provide specific benefits to individuals with Parkinson's disease, to determine if pursuing this route is worthwhile. Additionally, new technology would be required in this approach, as the system would no longer rely on a switch to send signals when pressed. Instead, the cuffs would need to detect key presses using sensors that respond to the user's input.

9.2 Project Limitations

It is important to consider the limitations of the project and how some of these can serve as starting points for future opportunities.

• Timeframe and Parkinson's Complexity
This graduation project lasted 100 working days, which is a limited timeframe for developing, testing, and evaluating a product, especially when considering the complexity of Parkinson's disease. As explained throughout this report, individuals with Parkinson's have diverse needs, as the disease progresses through different stages, symptoms, and personal preferences, particularly when using a keyboard. Despite the time constraints, a foundation was laid for exploring ways to empower individuals with PD by improving their interaction with keyboards. All participants were self-sufficient people with Parkinson's who regularly use keyboards. However, after conducting the focus group, it became clear just how many different layers and categories exist within Parkinson's. I believe the holistic approach taken in this phase was the right choice, though it did not allow for in-depth studies on specific cueing techniques.

• Testing
The participants with Parkinson's were only able to test the prototypes for a short period and not in their usual work environment or at home, where they could comfortably use the keyboard while performing tasks they regularly need to accomplish. Additionally, the prototypes were not full-size keyboards, which may have partially influenced some of the feedback. Given the complexity of the disease, participants might have believed certain features worked for them or didn't, but it's difficult to make definitive judgments without testing the product for an extended period.

• Cueing Techniques Limitations
Although not yet tested, it's important to highlight a general limitation of cueing techniques: over time, users might become accustomed to the cues, diminishing their effectiveness. This could make the signals less useful compared to the initial impact. Customizing the intensity and other parameters could help address this issue, but it's essential to keep this in mind for future evaluations to determine whether long-term exposure impacts the product's overall effectiveness and user engagement.

9.3 General Opportunities and future steps

Several key opportunities have been identified as recommended next steps to move the project forward:

1. Testing in Real-World Environments
The primary opportunity is to provide a full-size, working keyboard and cuffs to several people with Parkinson's for an extended period, such as a month, allowing them to use the product for their daily tasks. This would generate valuable feedback on the product's ergonomics, components, as well as both visual and haptic feedback, based on real-world usage. I believe, participants should be able to test the product in a comfortable and natural environment, without the presence of a researcher. They could provide feedback through structured questionnaires designed by the researchers to gather insights on their experience.

To achieve this, it is essential to develop a fully functional prototype that incorporates all the features outlined in this report for both the cuffs and the keyboard. A custom Printed Circuit Board (PCB) must be designed for the keyboard, as the hand-wired prototype is only suitable for early-stage testing. The custom PCB is vital for seamlessly integrating advanced features like AI-based prediction, haptic feedback, and visual feedback. It will allow for more efficient integration of components such as vibration motors, LEDs, and microcontrollers, providing a more reliable solution while effectively managing system complexity.

2. Specific Target Group
In my opinion, future phases of the project could benefit from a more focused approach by identifying specific user subsets based on factors like age, symptom severity, and common needs. Targeting a defined group would allow for product refinement to better serve their unique requirements. Once optimized for this audience, the product could then be scaled and adapted to accommodate the needs of other user groups, addressing a wider range of Parkinson's symptoms and offering more tailored support for various stages of the disease.

3. Haptic Feedback technologies
Haptic feedback has been one of the most positively received features, presenting strong potential for further development. Future research could focus on fine-tuning user preferences for wrist-based feedback and expanding it to the fingertips and arms. While the project has explored haptic technology at a basic level, deeper investigation could uncover the full complexity of haptics, with numerous technologies to explore. This could significantly improve both user experience and the product's effectiveness.

To better understand the complexity of haptic technology, it's essential to recognize that haptics is a family of various methods. Each technology communicates through touch differently: Vibrotactile feedback (used in this project) relies on small motors that produce vibrations. Ultrasonic mid-air haptics generates touch sensations without physical contact. Microfluidics uses air or liquid to apply pressure or temperature changes to the skin. Force control applies physical pressure to the user's body. Lastly, surface haptics modifies friction on touchscreens to create tactile sensations (See Appendix L).

Additionally, as we explore wearable technology, research into On-Skin Stimulation Devices for Haptic Feedback can provide valuable insights. Guo et al. (2021) emphasize the importance of on-skin electronics in healthcare, due to their exceptional performance and wearable comfort. High-performance on-skin stimulators need to be lightweight, soft, and thin to ensure accurate feedback. Key stimulation methods include electrotactile stimulation for high resolution and fast responses, stretchable wearable heaters for thermal feedback, and mechanotactile/vibrotactile stimulators for comfortable tactile sensations. Exploring these technologies can significantly enhance haptic feedback in future product versions.

4. Haptic Feedback integrated in daily tasks to improve parkinson's symptoms.
As previously mentioned, haptic feedback has shown therapeutic benefits. Several studies have investigated its use on various body parts. For instance, the study "Safety and Tolerability of a Wearable, Vibrotactile Stimulation Device for Parkinson's Disease" (Tabacof et al., 2021) found that vibrations on the wrists and ankles may reduce resting tremors. Similarly, Stanford researcher Peter Tass developed a fingertip vibrating glove to alleviate symptoms, offering a non-invasive alternative to deep brain stimulation, which can have side effects (Stanford Medicine, 2024).

Although research in this area is still developing, a key hypothesis of this project is that integrating vibrations into a keyboard or wearable cuff could enhance user interaction and provide seamless rehabilitation during daily tasks, without requiring extra time or causing side effects. An initial questionnaire revealed that many users spend several hours daily on computers, supporting the potential for this approach. This assumption warrants further investigation with expert input.

5. Streamlining OnCue: Transitioning from a System to a Compact Product
As previously mentioned, one promising direction is to simplify OnCue by removing the need for a dedicated keyboard and allowing the haptic cuffs to function independently. The cuffs could detect key presses using sensors, such as monitoring wrist movements during typing. Future research in haptic technology and machine learning could explore detecting bradykinesia, providing a more comprehensive solution. Additionally, keeping the OnCue software for deeper personalization would enhance the product's usability, all while maintaining its compact design.

9.4 Price evaluation

At this stage of the project, preliminary considerations can be made regarding the potential price of the product. To do this, comparable products on the market that incorporate similar technologies can be analyzed to estimate where the product might fit in terms of pricing.
As a benchmark, the ZSA Moonlander was considered, a high-end split keyboard designed for ergonomics. It features mechanical switches, extensive customization options, backlighting, and a palm rest, and is priced at approximately €310 (Fig. 118). Given that this product also integrates haptic feedback, its price may be slightly higher.
For the haptic cuffs, smart bands serve as a useful comparison, as they are the most similar products. In this case, more affordable options were examined rather than high-end models, since the current haptic technology requires fewer features. A relevant reference is the Xiaomi Band 8, which sells for around €20 (Fig. 117) (Xiaomi Nederland, n.d.).
By making an approximate overall calculation (considering that the bands for this product would likely cost a bit less and the keyboard slightly more) it is estimated that the final retail price could be around €350.

Fig. 117 Xiaomi Band 8


Fig. 118 ZSA Moonlander

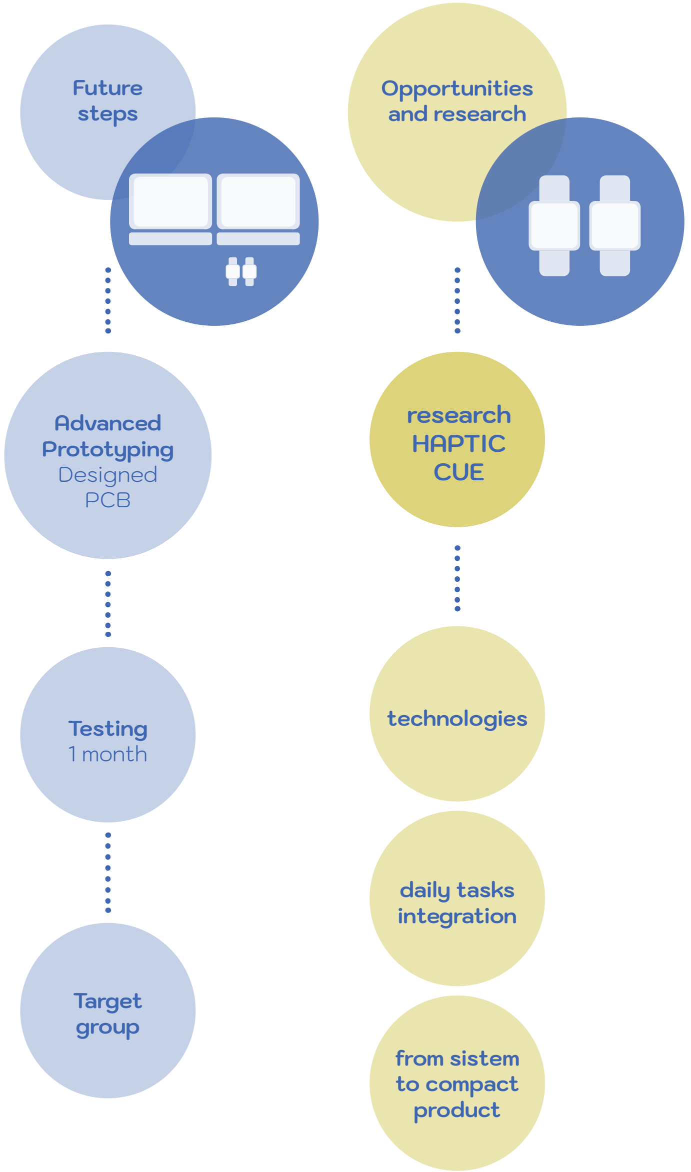


Fig. 119 General Opportunities and future steps

9.5 Reflection

9.5.1 Use of AI in the process

It is well known that artificial intelligence is increasingly becoming a part of our daily lives. I find it incredible what AI, specifically ChatGPT, has allowed me to achieve in my graduation project. I primarily used it for three main tasks: improving my writing skills in English, which is my second language; programming with Arduino; and as a tutor for understanding what is possible with electronics.

Before starting this project, I had almost no knowledge of electronics or programming. However, with the help of ChatGPT, I was able to clarify most of my doubts and verify whether my ideas were correct. I also learned how to ask questions effectively, understanding the importance of being precise and using the right keywords.

When developing complex code, my approach has been to work step-by-step. I would start by writing simple code, test it to see if it worked, and then ask ChatGPT to help implement additional features. For my prototypes, I mainly used the Arduino Micro, as ChatGPT taught me that it is ideal for keyboards due to its size and functionality. I would inform ChatGPT about what was connected to the ground and the digital pins, and then ask it to provide the appropriate code, (see Appendix M for an example of a prompt given).

While this technology is not 100% reliable—sometimes a request would go smoothly, and other times, a slightly different phrasing would produce non-working code—I learned to save the working codes generated by ChatGPT. For subsequent prototypes, I would ask the AI to follow the same coding style, which helped me achieve consistent and functional results.

I must admit, I didn't expect to be able to create these prototypes mostly on my own, without direct human assistance. A year ago, I would have needed someone skilled in programming to write the code for me. While YouTube was helpful for the mechanical aspects thanks to the maker community, I wouldn't have been able to write the necessary code so quickly without the help of ChatGPT.

9.5.2 Personal reflection

I genuinely enjoyed dedicating the past five months to this project. It was my first experience working in the field of design for health and social well-being, and I believe I've learned a great deal along the way. I'm pleased with the choice I made, and I'm confident that the knowledge I've gained during this graduation project will be invaluable in my future professional endeavors. Channeling design into something that benefits the community feels like a fulfilling career path, one where this profession can truly contribute to improving people's lives.

As with any project, there are always some "what-ifs" at the end—could I have done more? Could I have taken a faster or different route to achieve better results? There's always room for improvement. However, it's also important to recognize that design is an iterative process, involving many attempts and shifts in direction. I hope, in my own small way, that I've contributed to this important cause.

Regarding the design of the keyboard, from the beginning, I felt that all the key elements were in place: focusing on ergonomics and drawing inspiration from user questionnaires and online forums where people with Parkinson's share tips to improve their daily lives.
The implementation of cueing, however, was more challenging due to the broad range of possibilities. Taking a holistic approach, I explored various methods without always being able to definitively determine what worked and what didn't. Initially, I adopted a more analytical approach because I genuinely wanted to create something useful, backed by solid data, but perhaps I was simply eager to deliver something meaningful within a limited time frame.
After realizing this, I took the time to reflect more deeply on the different possibilities for achieving similar outcomes and understood that user experience should be the core focus around which my evaluation process revolved.
I accepted that my role wasn't necessarily to find the perfect solution, but rather to identify what didn't work, provide direction for the next phases of the project, and move forward from there.
Having two focus groups, especially the second one where I was able to present my prototypes to actual users and receive feedback, was both insightful and a rewarding experience.

I must admit that concluding this graduation project at this point leaves me with somewhat bittersweet feelings. I would love to continue, refine, and explore further, in close collaboration with the project's target group.

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Fig. 119
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Appendix

Appendix A

Questionnaire

6. How does bradykinesia (slowed movement) affect your ability to type or use a keyboard?

	+ time	+ mistakes	+ dictation function	+ tired and frustrated
1. It takes longer, takes more energy, I have to correct more often.				
2. It can a very long time to create a document which is very frustrating. The amount of errors also significantly increases.				
3. No, still going fine.				
4. Typing takes a lot of energy, operating a regular mouse is an even bigger problem.				
5. I rarely type. I mostly use the dictaphone function.				
6. My left can't keep up so I'm always correcting. Losing my train of thought as I'm writing a book.				
7. Frustrating especially because it makes it harder to type so more lists are made which makes it take even longer.				
8. Takes forever to type an email.				
9. I don't know.				
10. When I'm tired, I make more typing errors.				
11. I have difficulty with it.				
12. Typing goes well. Much better than writing or using one finger on the smartphone.				
13. It takes me a long time to type. I have difficulty using a mouse.				
14. I can't get my fingers to touch the correct keys and it's soooooo slow and my hands don't want to work.				
15. Stresss				
16. More and more spelling mistakes, missing or skipping keys.				
17. More typing errors than before.				
18. It is becoming more difficult to type.				
19. A lot, it is my primary complaint. I have to take much more Levodopa than I feel comfortable with because I still need to work and voice to text is too slow as well.				

8. Can you describe a time when using a keyboard was very challenging?

	MEDICATION / off-period	TASKS / drafting report, online banking, writing, mails	FEELINGS / avoidance behaviour, embarrassment	Not challenging
1. I would **not** really **feel like doing it**, knowing it would take a lot of effort. I would have to answer mails, with quite some text to write. **I tense up more, because my left hand does not function well**. It would not find keys quick enough, which results in my right hand finding the keys to soon and therefore the letters in the words not being in the correct order. **Also my left fingers would 'stick' on keys**, **not moving up fast enough**. Resulting in 'eeeeeeeeeeeee' or 'sssssssss' for instance, which I then had to correct. It also means **I can concentrate less** on content, because the functioning of my hand is distracting, as are the mistakes I made.				
2. Before my diagnosis and I started taking C/L I had come to the conclusion I was going to have to look into **dictation software** or **look at finding a job that didn't require me to type**.				
3. Not a challenge, still going well.				
4. When tired, preparing **reports** for work.				
5. When making **lists**.				
6. Try to **write a book** but I get **frustrated** now. It's making me **lose interest** in the project				
7. Creating **documents** for work, especially when I have to **add graphics** or use **multiple fonts**.				
8. **Typing in front of lots or people** and **twitchy fingers** hit the wrong keys.				
9. I often type on my phone. The keys are too small.				
10. Not very challenging.				
11. In off moment				
12. During the off-period, it is (**mainly on the right**) more difficult to move the fingers properly.				
13. Trying to do **online banking** and using the **number pad** correctly.				
14. When I'm "off" it's very challenging because I can't move well and have no feeling my hands wouldn't press the right keys.				
15. End of tablet.				
16. Especially when **writing reports/long emails**, more than a few sentences.				
17. While writing **reports** or **long emails**.				
18. Typing incorrectly.				
19. **Every day** of my **work life**. I **cannot take notes** in meetings (I work remotely).				

7. Are there other symptoms (e.g., tremors, stiffness) that also impact your keyboard use?

1. No, just the bradykinesia
2. Twitching
3. Not yet
4. Stiffness of the fingers, slow typing, the harder the keystroke, the more difficult it is. Soft touch keyboard works best.
5. No
6. Slight tremor and stiff fingers
7. Tremors
8. Twitchy fingers hit the wrong keys
9. My thoughts are faster than I can type, resulting in strange sentences sometimes.
10. No
11. Double tapping, pain from stiffness
12. No
13. Stiffness and tremors
14. Bradykinesia, dyskinesia, cramping, loss of feeling and function
15. Stiffness
16. No
17 .No
18. Stiffness
19. I have action tremor

9. How did you feel?

1. Frustrated
2. Depressed and frustrated
3. Good
4. Frustrated by making typing errors and correcting them
5. Annoyed
6. Frustrated. I have so much to tell but the typing halts that ability
7. Frustrated and defeated
8. Frustrated
9. Good
10. Not applicable
11. Powerless, inadequate, isolated, lonely
12. Impatient and a bit sad
13. Frustrated and angry
14. Frustrated, useless
15 .Good
16. Very annoying, takes more time, and you start avoiding long texts
17. Annoying, avoid typing long texts
18. Okay
19. Debilitated, unprofessional, afraid I'd lose my job

10. Have you made any adjustments or found any tools that help you use a keyboard more effectively?

1. No, I used dictation for a while. That works pretty well, but still needs a lot of correcting.
2. Taking my meds
3. **Illuminated keyboard**
4. **Soft touch works better**
5. **I use the dictation function of my laptop/phone**
6. Tried dictation but you have to do far more editing afterwards. So that's discouraging as well.
7. No
8. No
9. Not applicable
10. No
11.No
12. No. Except that I use a mouse and not the touchpad. It is much too sensitive.
13. **No—I don't know where to go for help**
14. **A stylus but it needs to be big and firm**
15. No
16. Temporarily operated the mouse with the left hand, now again with the right, due to medication having more control over right arm/hand.
17. No
18. No
19. Dragons peak is ok, contour roller mouse

11. Do you use any accessibility features or assistive technologies for other Parkinson's symptoms? If so, which ones, and how do they help?

1. Dictation for this typing problem. But I can't use that everywhere. In Word and E-mail, it is pretty good.
2. No
3. No
4. Ergonomic mouse, voice program
5. I don't understand this question.
6. No
7. None
8. Yes, only dictation in Word
9. Mouse
10. Orthotic insoles. Music
11. No
12. No.
13. Siri on my phone. Alexa in my house.
14. A stylus helps accuracy on my phone. My iPad is much easier than using a laptop keyboard.
15. DBS (Deep Brain Stimulation)
16. No
17. No
18. No
19. DragonSpeak (likely referring to the speech recognition software Dragon NaturallySpeaking)

13. What features would you like to see in a keyboard designed specifically for individuals with Parkinson's? Are there any specific modifications (e.g., key size, spacing, feedback) that you think would help?

1. I want the same size, really. Because that is what my hands are used to. But feedback may work.
2. Unsure
3. Fine as it is
4. Keys that are easy to press, as few keys as possible
5. No idea
6. I don't know
7. Bigger keys
8. I am not sure!
9. Larger spacing between keys or bigger keys so you don't hit 2 or the wrong letters
10. I don't know

11. No idea, support for the hands to reduce pain and strain in the wrists and arms
12. A customized mouse. Double-clicking is becoming more difficult (mouse is already set to slow).
13. Size, keys in alphabetical order. One key functions for capitals
14. Bigger keys with more space between them. Touch screen like an iPad
15. No
16. I really have no idea what could help
17. No idea
18. Larger keyboard
19. Bigger keys maybe? But then the hand would have to strain too much to reach. It's possible that using AI to see my most frequently occurring mistakes would help?

14. How do you believe that a better interaction with the computer keyboard could affect your daily life and overall quality of life?

1. Less frustration, less time wasted, less energy.
2. Reduce frustration. Ensure I can continue to work and earn an income.
3. Nothing is fortunately still going well.
4. Undoubtedly saves energy and frustration.
5. It will, for example, make creating a report somewhat simpler.
6. Tremendously.
7. Eliminate the frustration and feeling of defeat that comes with Parkinson's.
8. Save time.
9. Prefer larger keys or more space between keys, stylus just like for a tablet.
10. Less frustration.
11. Social contact, filling of free time.
12. Adapted mouse.
13. Easier accessibility to the internet. Less frustration.
14. I keep in touch with the world and my friends overseas and if it was easier to use I wouldn't get so frustrated. Better dictation would be great! By the time I fix all the mistakes it's written I may have well typed it myself.
15. No.
16. Again no idea. I don't know how it could be made easier or better.
17. I have no idea.
18. Work faster.
19. It could extend my career and income. Improve confidence and make me less reticent to start the work day. I'd be very excited to demo any products you test.

Appendix B

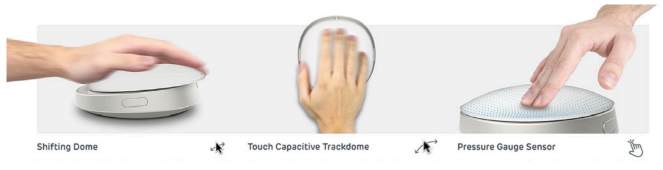
Products designed to address Parkinson's symptoms.

Shift

Description

Shift is an adaptive pointing device that offers an intuitive and accessible way for users with hand tremors to use a computer and regain their digital mobility.

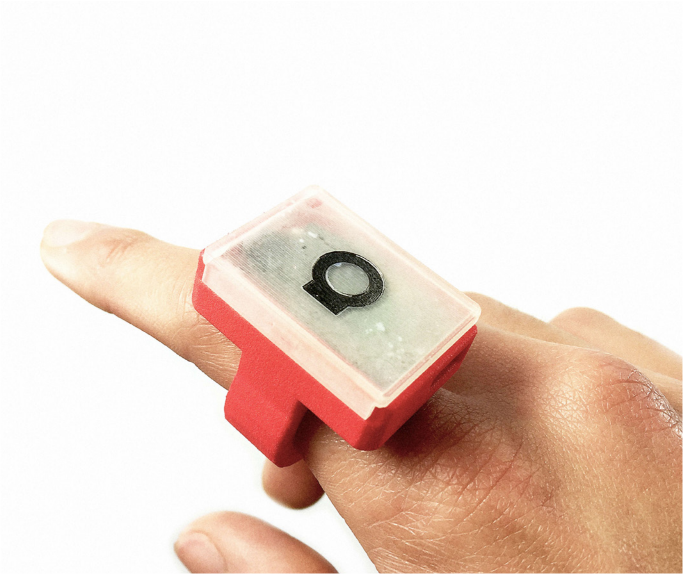
A shifting dome provides precise translational control, and a pressure-sensitive track pad tracks large coarse movements while preventing unintentional clicks, improving accuracy that would otherwise be impossible with a traditional mouse. Lastly, it also contains programmable buttons that can be used as voice-to-text for people with limited keyboard abilities, or as back and forth buttons.



Concept

Source

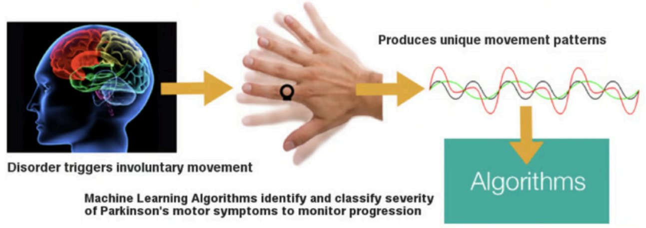
https://newsroom.carleton.ca/story/carleton-student-designs-award-winning-computer-mouse-for-hand-tremors/



OneRing

Description

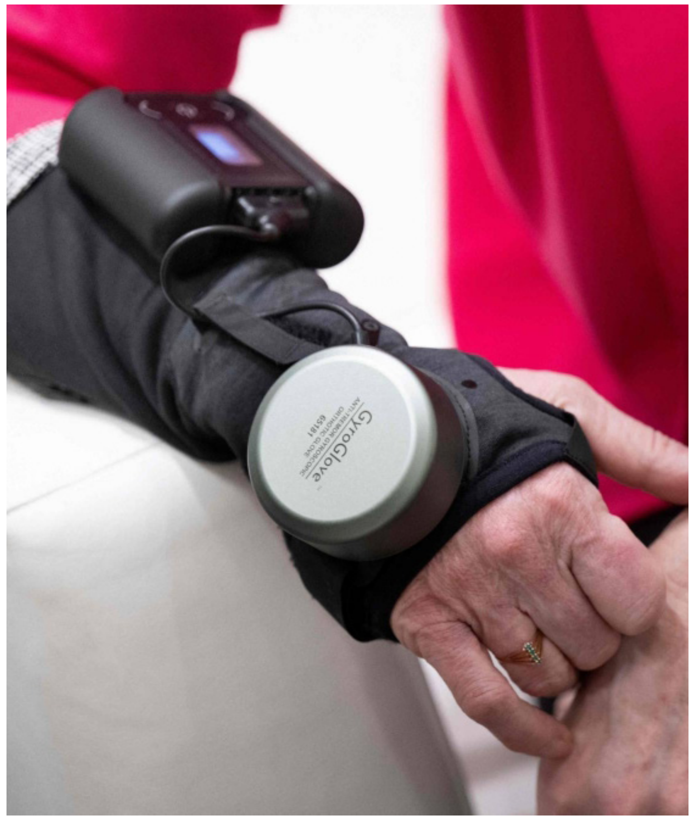
OneRing identifies Parkinson's motor symptoms to generate daily patient reports and help doctors prescribe medications more accurately.
Its intelligent machine learning technology has been trained to model various Parkinson's movement patterns including dyskinesia, bradykinesia, and tremor in order to generate smart patient reports on a daily basis. These reports provide physicians with time-stamped analytics about their patient's movement severity at each hour of the day; allowing them to better prescribe medications. With smarter medications dosages/timings, Parkinson's patients would get quicker relief from their motor symptoms.



Concept

Source

https://oneringforpd.com/



GyroGlove

Description

The GyroGlove is an advanced hand stabilizer. It is a wearable device that fits over the hand and uses miniaturized gyroscopes to generate a force that counteracts hand tremors. This hand-stabilizing glove is designed to provide wearers with more control over their movements by using advanced gyroscopic technology. The glove features a large gyroscopic motor on the back, which is connected to a battery pack, and this setup helps stabilize the hand.

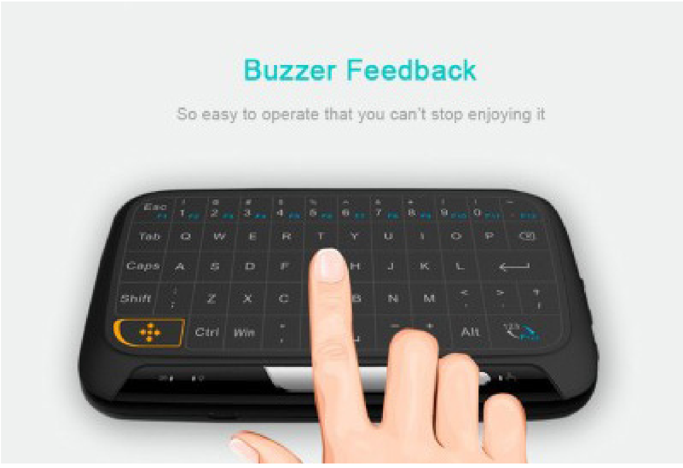
Available on the market

Source

https://gyrogear.co/product/gyroglove/

Appendix C

Examples of keyboards available on the market that implement cueing.



Somatosensory cueing

Wireless keyboard with touch screen with buzzer feedback.

https://www.shopitnow.gr/wireless-keyboard-with-touch-screen

Auditory cueing

Enhanced Auditory Feedback: The keyboard's integrated piezo buzzer enriches your typing with auditory feedback. Each keystroke can play a noise or you can program a 'startup' noise. This hackable speaker allows for further customization options.

https://www.boardsource.xyz/products/equals-60

Visual cueing

Mechanical keyboard with 7 color backlit mode.

https://www.prohavit.com/it-eu/blogs/havit/tutorial-how-to-change-backlit-colors-on-hv-kb366l-mechanical-keyboard

Appendix D

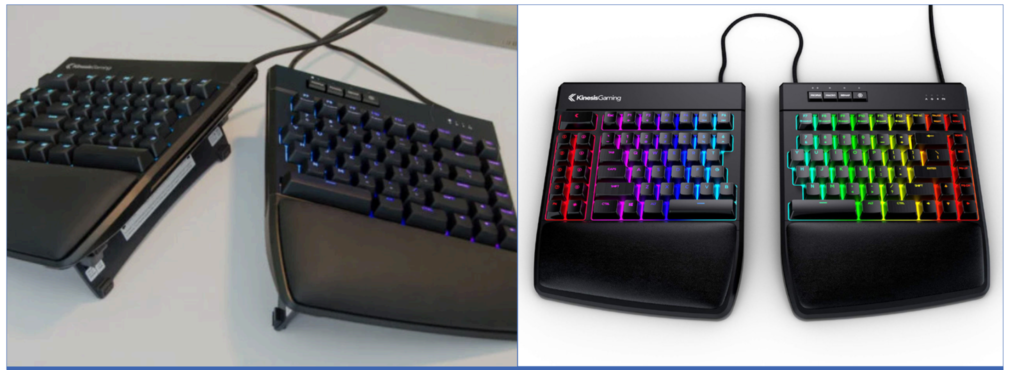
Overview of the best ergonomic keyboards on the market.


Logitech Ergo K860


Logitech Wave Keys


Kinesis TKO Gaming Keyboard


Cloud Nine ErgoTKL


Kinesis Freestyle Edge RGB Split Mechanical Gaming


Matias Ergo Pro (2020)


Keychron Q11


ErgoDox EZ

Appendix E

Concept 1 - Vibrating keys

This Arduino code implements a hand-wired matrix keyboard that provides tactile feedback via vibration motors and simulates keypresses using the Keyboard.h library.

Key Features:

Matrix Keyboard Setup: The keyboard is organized in a 3×4 matrix, where each key corresponds to a specific character (keymap), efficiently scanned using row and column pins.

Keypress Detection: When a key is pressed, the Arduino sends the corresponding character to the computer using Keyboard.press(), mimicking a real keyboard.

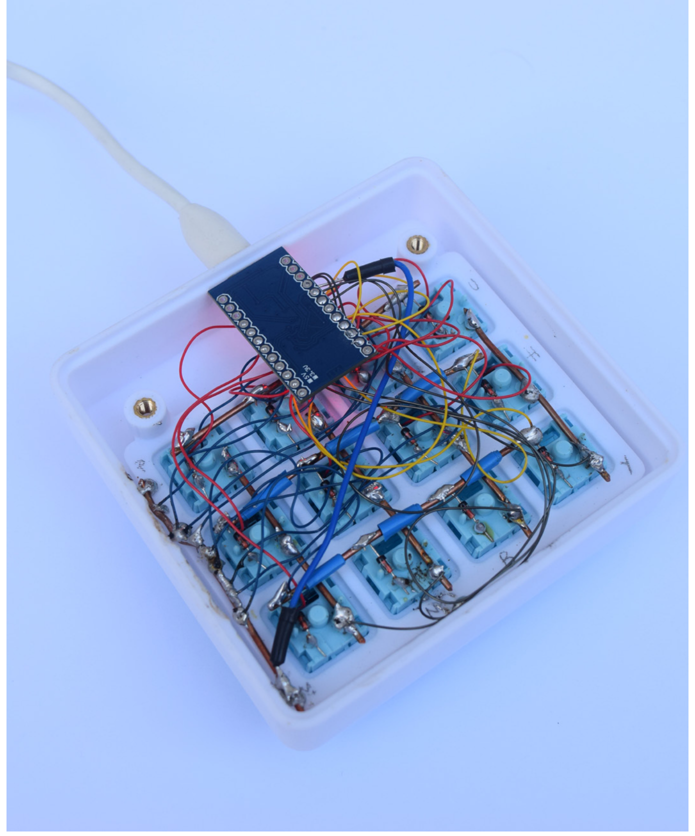
Vibration Feedback: Each key activates a corresponding vibration motor, providing physical feedback when pressed and deactivating upon release.
State Tracking and Debouncing:

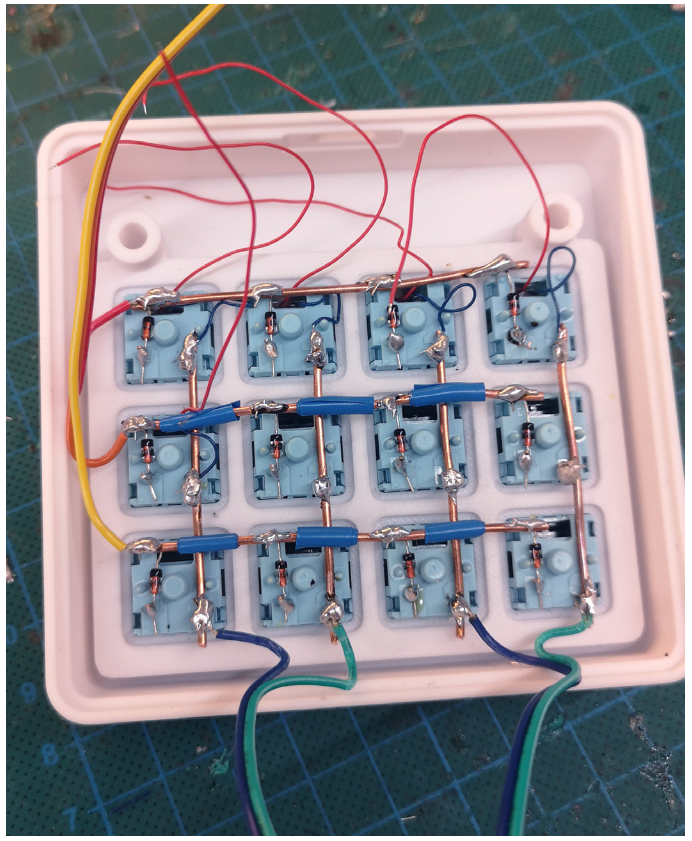
The previous state of each key is tracked (previousState) to prevent repeated key actions, and short delays ensure stable key detection and debouncing.

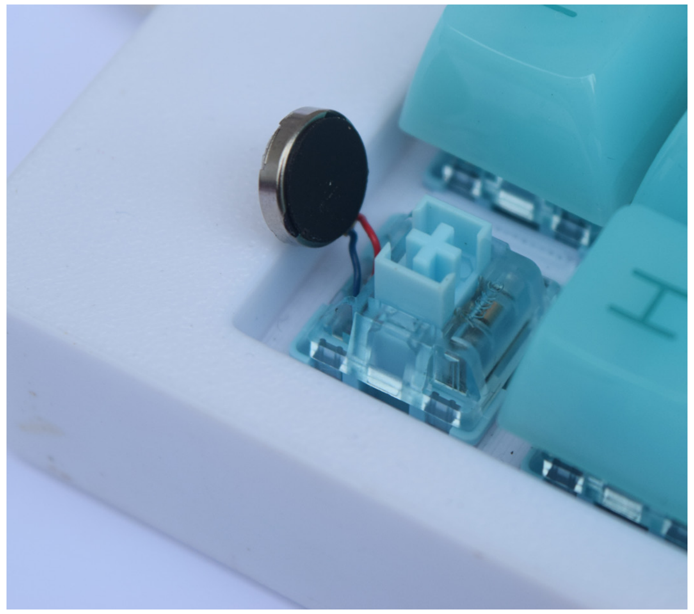
This ensures smooth keypress detection with both auditory and tactile feedback.

CODE:

```
#include <Keyboard.h>

// Definizione dei pin delle righe
const int rowPins[3] = {5, 6, 7};

// Definizione dei pin delle colonne
const int colPins[4] = {8, 4, 3, 2};

// Definizione della mappatura dei tasti
char keymap[3][4] = {
  {‘P’, ‘O’, ‘I’, ‘U’},
  {‘L’, ‘K’, ‘J’, ‘H’},
  {‘M’, ‘N’, ‘B’, ‘Y’}
};

// Definizione dei pin per i motori di vibrazione
const int motorPins[9] = {14, 16, 10, 9, 15, A0, A1, A2, A3}; //
P, O, I, U, H, J, K, L, M

// Mappatura dei tasti ai pin dei motori
const char motorKeys[9] = {‘P’, ‘O’, ‘I’, ‘U’, ‘H’, ‘J’, ‘K’, ‘L’, ‘M’};

// Stato precedente dei tasti
bool previousState[3][4];

void setup() {
  // Inizializza le righe come output e impostale a HIGH
  for (int row = 0; row < 3; row++) {
    pinMode(rowPins[row], OUTPUT);
    digitalWrite(rowPins[row], HIGH);
  }

  // Inizializza le colonne come input pullup
  for (int col = 0; col < 4; col++) {
    pinMode(colPins[col], INPUT_PULLUP);
  }

  // Inizializza i pin dei motori come output e impostali a LOW
  for (int i = 0; i < 9; i++) {
    pinMode(motorPins[i], OUTPUT);
    digitalWrite(motorPins[i], LOW);
  }

  // Inizializza lo stato precedente dei tasti
  for (int row = 0; row < 3; row++) {
    for (int col = 0; col < 4; col++) {
      previousState[row][col] = HIGH;
    }
  }

  // Inizializza la comunicazione seriale per il debug
  Serial.begin(9600);

  Keyboard.begin();
}

void loop() {
  for (int row = 0; row < 3; row++) {
    // Imposta tutte le righe a HIGH
    for (int r = 0; r < 3; r++) {
      digitalWrite(rowPins[r], HIGH);
    }

    // Imposta la riga corrente a LOW
    digitalWrite(rowPins[row], LOW);
     delayMicroseconds(5); // Piccolo ritardo per stabilizzare
il segnale

    for (int col = 0; col < 4; col++) {
      // Leggi lo stato del tasto
      bool keyState = digitalRead(colPins[col]);

      // Debug per monitorare lo stato del tasto
      Serial.print(“Riga: “);
      Serial.print(row);
      Serial.print(“, Colonna: “);
      Serial.print(col);
      Serial.print(“, Stato tasto: “);
      Serial.println(keyState);

      // Se lo stato del tasto è cambiato
      if (keyState != previousState[row][col]) {
        previousState[row][col] = keyState;

        if (keyState == LOW) {
          // Il tasto è premuto
          if (keymap[row][col] != ‘ ‘) {
            Keyboard.press(keymap[row][col]);
            Serial.print(“Premuto tasto: “);
            Serial.println(keymap[row][col]);

            // Attiva il motore di vibrazione corrispondente
            for (int i = 0; i < 9; i++) {
              if (keymap[row][col] == motorKeys[i]) {
                digitalWrite(motorPins[i], HIGH); // Imposta a HIGH
                Serial.print(“Attivato motore per il tasto: “);
                Serial.println(keymap[row][col]);
                break;
              }
            }
          }
        } else {
          // Il tasto è rilasciato
          if (keymap[row][col] != ‘ ‘) {
            Keyboard.release(keymap[row][col]);
            Serial.print(“Rilasciato tasto: “);
            Serial.println(keymap[row][col]);

            // Disattiva il motore di vibrazione corrispondente
            for (int i = 0; i < 9; i++) {
              if (keymap[row][col] == motorKeys[i]) {
                digitalWrite(motorPins[i], LOW); // Imposta a LOW
                Serial.print(“Disattivato motore per il tasto: “);
                Serial.println(keymap[row][col]);
                break;
              }
            }
          }
        }
      }
    }

    // Riporta la riga corrente a HIGH
    digitalWrite(rowPins[row], HIGH);
     delayMicroseconds(5); // Aggiungi un piccolo ritardo per
stabilizzare il segnale
  }

  delay(10); // Aggiungi un piccolo ritardo per debouncing
}
```



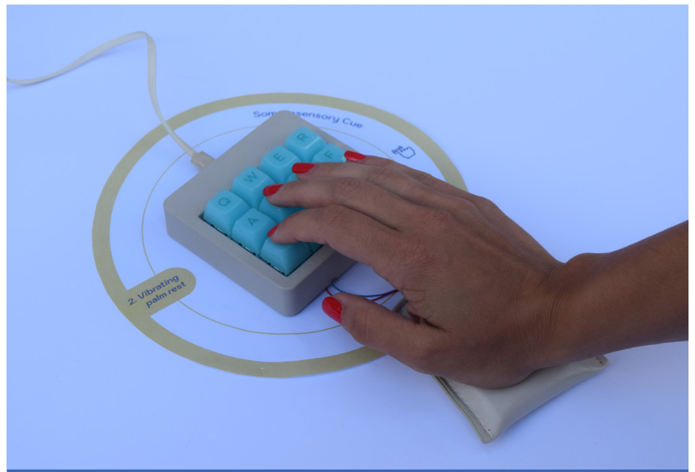




Hardware:

This prototype uses a Pro Micro board and consists of 12 switches. Each switch has two pins: the left pins are connected vertically, while the right pins are connected horizontally. Each left pin is also connected to a Zener diode before being connected with the other pins, forming a matrix. Each row and column is then connected to a digital pin on the Pro Micro board.

Additionally, some switches incorporate a vibrating motor. The positive wire of each vibrating motor is connected to a digital pin on the Pro Micro board, while the negative wires are connected together and then to the GND of the board. Not all switches have a vibrating motor, as the Pro Micro does not have enough digital pins to support that.



Concept 2 - Vibrating palm rest

This code uses the HID-Project.h library to send key presses and provide feedback via a vibration motor connected to pin A2.

Key Functions:

Single Key Press: When a key is pressed, the corresponding key signal is sent to the computer and the motor vibrates for 100 ms to provide feedback.

Long Press Detection: If a key is held for more than 1 second, the motor starts an intermittent vibration pattern (100 ms on, 100 ms off) until the key is released. This helps the user know they are holding a key too long.

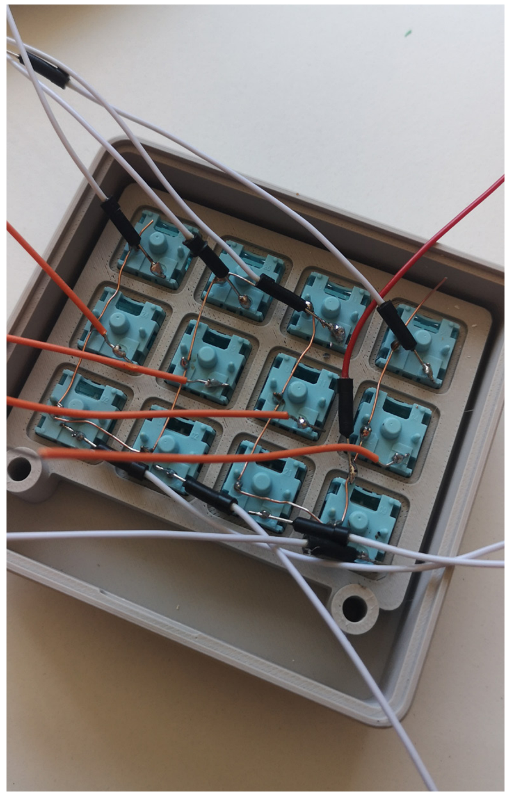
Inactivity Reminder: If no key is pressed for 7 seconds, the motor vibrates 5 times (200 ms on, 200 ms off) to prompt the user to continue typing.

The code uses millis() to track time and handle timed events like long presses and inactivity. It resets timers and manages motor control based on key press state changes.

Code:

```
#include "HID-Project.h"

const int switchQ = 5;   // q - collegata al pin 5 (d)
const int switchW = 4;   // w - collegata al pin 4 (f)
const int switchA = 9;   // a - collegata al pin 9 (q)
const int switchS = 8;   // s - collegata al pin 8 (c)
const int switchD = 7;   // d - collegata al pin 7 (w)
const int switchF = 6;   // f - collegata al pin 6
const int switchC = 16;  // c - collegata al pin 16 (z)
const int switchZ = 14;  // z - collegata al pin 14
const int switchE = 3;   // e - collegata al pin 3
const int switchR = 2;   // r - collegata al pin 2
const int switchX = 15;  // x - collegata al pin 15
const int switchV = 10;  // v - collegata al pin 10

const int vibrationMotor = A2; // Pin del motore di vibrazione

// Stato attuale di ciascun tasto
bool switchState[12] = {false, false, false, false, false, false,
false, false, false, false, false, false};
// Stato precedente di ciascun tasto
bool prevSwitchState[12] = {false, false, false, false, false,
false, false, false, false, false, false, false};

// Timer per gestire le vibrazioni multiple
unsigned long pressTime = 0; // Tempo di pressione del tasto
unsigned long currentMillis = 0; // Tempo corrente
unsigned long vibrationStart = 0;  // Inizio del ciclo di
vibrazioni intermittenti
unsigned long lastKeyPressTime = 0; // Ultima pressione del
tasto per l'inattività
const unsigned long longPressDuration = 1000;  // Durata
pressione lunga in millisecondi (1 secondo)
const unsigned long inactivityDuration = 7000;  // Durata di
inattività in millisecondi (7 secondi)
const unsigned long vibrationInterval = 100;  // Durata di
ogni intervallo di vibrazione intermittente
const unsigned long inactivityVibrationDuration = 200; //
Vibrazione in caso di inattività (200 ms)
bool motorState = false;
bool longPressActive = false; // Indica se è attiva la vibrazione
intermittente
bool vibrationStarted = false; // Indica se la vibrazione
intermittente è iniziata

void setup() {
  pinMode(switchQ, INPUT_PULLUP);
  pinMode(switchW, INPUT_PULLUP);
  pinMode(switchA, INPUT_PULLUP);
  pinMode(switchS, INPUT_PULLUP);
  pinMode(switchD, INPUT_PULLUP);
  pinMode(switchF, INPUT_PULLUP);
  pinMode(switchC, INPUT_PULLUP);
  pinMode(switchZ, INPUT_PULLUP);
  pinMode(switchE, INPUT_PULLUP);
  pinMode(switchR, INPUT_PULLUP);
  pinMode(switchX, INPUT_PULLUP);
  pinMode(switchV, INPUT_PULLUP);

  pinMode(vibrationMotor, OUTPUT);  // Imposta il pin del
motore come output (A2)
  digitalWrite(vibrationMotor, LOW); // Inizialmente spegne il
motore

  // Inizializzazione tastiera e consumer
  Keyboard.begin();
  Consumer.begin();
}

void loop() {
  // Aggiorna il tempo corrente
  currentMillis = millis();

  // Leggi lo stato attuale di ciascun tasto
  switchState[0] = !digitalRead(switchQ); // q
  switchState[1] = !digitalRead(switchW); // w
  switchState[2] = !digitalRead(switchA); // a
  switchState[3] = !digitalRead(switchS); // s
  switchState[4] = !digitalRead(switchD); // d
  switchState[5] = !digitalRead(switchF); // f
  switchState[6] = !digitalRead(switchC); // c
  switchState[7] = !digitalRead(switchZ); // z
  switchState[8] = !digitalRead(switchE); // e
  switchState[9] = !digitalRead(switchR); // r
  switchState[10] = !digitalRead(switchX); // x
  switchState[11] = !digitalRead(switchV); // v

  bool keyPressed = false;

  for (int i = 0; i < 12; i++) {
    // Se il tasto è stato appena premuto
    if (switchState[i] && !prevSwitchState[i]) {
```

```
        pressTime = currentMillis;  // Memorizza il tempo di pressione
      lastKeyPressTime = currentMillis;  // Resetta il timer di inattività

      // Vibrazione singola all'inizio per 100 ms
      digitalWrite(vibrationMotor, HIGH);
      delay(100);
      digitalWrite(vibrationMotor, LOW);

      // Invio del carattere premuto
      switch (i) {
        case 0: Keyboard.press('q'); break;
        case 1: Keyboard.press('w'); break;
        case 2: Keyboard.press('a'); break;
        case 3: Keyboard.press('s'); break;
        case 4: Keyboard.press('d'); break;
        case 5: Keyboard.press('f'); break;
        case 6: Keyboard.press('c'); break;
        case 7: Keyboard.press('z'); break;
        case 8: Keyboard.press('e'); break;
        case 9: Keyboard.press('r'); break;
        case 10: Keyboard.press('x'); break;
        case 11: Keyboard.press('v'); break;
      }

      Keyboard.releaseAll();  // Rilascia tutti i tasti
    }

    // Se il tasto è tenuto premuto
    if (switchState[i]) {
      keyPressed = true;
      // Se il tasto è tenuto premuto per più di 1 secondo
        if (currentMillis - pressTime > longPressDuration && !vibrationStarted) {
        longPressActive = true;
          vibrationStarted = true;  // Segna che la vibrazione intermittente è iniziata
        vibrationStart = currentMillis;  // Inizia il ciclo di vibrazioni
      }
    }

    // Se il tasto viene rilasciato, spegni tutto
    if (!switchState[i] && prevSwitchState[i]) {
      longPressActive = false;
      vibrationStarted = false;
      digitalWrite(vibrationMotor, LOW);
    }

    // Aggiorna lo stato precedente
    prevSwitchState[i] = switchState[i];
  }

  // Gestisci la vibrazione intermittente se il tasto è tenuto premuto
  if (longPressActive) {
    if (currentMillis - vibrationStart >= vibrationInterval) {
      motorState = !motorState;
      digitalWrite(vibrationMotor, motorState ? HIGH : LOW);
     vibrationStart = currentMillis;  // Aggiorna il tempo di inizio per il prossimo ciclo
    }
  }

   // Gestisci la vibrazione in caso di inattività (nessuna pressione per 7 secondi)
    if (!keyPressed && (currentMillis - lastKeyPressTime > inactivityDuration)) {
    // Vibrazione 5 volte (200 ms ON, 200 ms OFF)
    for (int i = 0; i < 5; i++) {
      digitalWrite(vibrationMotor, HIGH);
      delay(inactivityVibrationDuration);  // Vibrazione per 200 ms
      digitalWrite(vibrationMotor, LOW);
      delay(inactivityVibrationDuration);  // Pausa per 200 ms
    }
    lastKeyPressTime = currentMillis;  // Resetta il timer dopo la vibrazione di inattività
  }

  delay(10);  // Piccola pausa per evitare letture multiple
}
```



Concept 3 - Vibrating cuff

Key Input: The code reads the state of 12 physical keys connected to the Arduino.

Key Press Detection: If a key is pressed, the corresponding keyboard signal (e.g., 'r', 'e', etc.) is sent to the computer via HID.

Vibration During Key Press: If any key is pressed, the vibration motor is turned on.

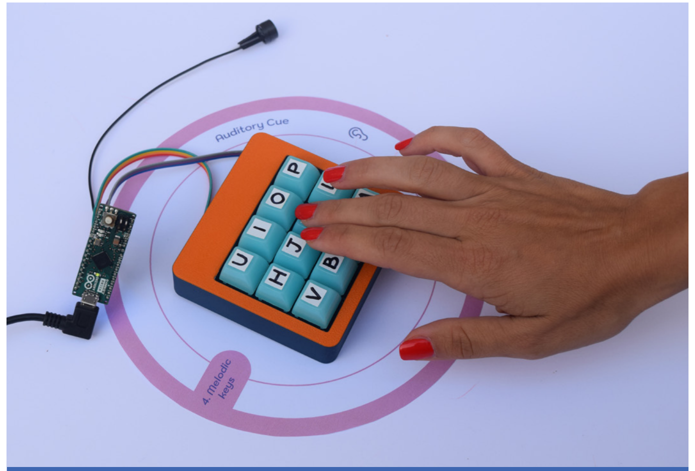
Inactivity Timer: If no key is pressed for 5 seconds, the vibration motor runs a reminder sequence of 5 short vibrations.

Resetting the Timer: After a key press or vibration sequence, the inactivity timer is reset.

CODE:

```
#include "HID-Project.h"

const int switch1 = 2;  // r
const int switch2 = 3;  // e
const int switch3 = 7;  // w
const int switch4 = A2;  // q
const int switch5 = 4;  // f
const int switch6 = 5;  // d
const int switch7 = 10;  // s
const int switch8 = 15;  // a
const int switch9 = 8;  // v
const int switch10 = 9; // c
const int switch11 = 16; // x
const int switch12 = 14; // z

const int vibrationMotor = 6; // Pin del motore di vibrazione
const unsigned long inactivityTimeout = 5000; // 5 secondi di inattività
unsigned long lastKeyPressTime = 0; // Timer per l'ultimo tasto premuto

// Stato attuale di ciascun tasto
bool switchState[12] = {false, false, false, false, false, false, false, false, false, false, false, false};
// Stato precedente di ciascun tasto
bool prevSwitchState[12] = {false, false, false, false, false, false, false, false, false, false, false, false};

void setup() {
  pinMode(switch1, INPUT_PULLUP);
  pinMode(switch2, INPUT_PULLUP);
  pinMode(switch3, INPUT_PULLUP);
  pinMode(switch4, INPUT_PULLUP);
  pinMode(switch5, INPUT_PULLUP);
  pinMode(switch6, INPUT_PULLUP);
  pinMode(switch7, INPUT_PULLUP);
  pinMode(switch8, INPUT_PULLUP);
  pinMode(switch9, INPUT_PULLUP);
  pinMode(switch10, INPUT_PULLUP);
  pinMode(switch11, INPUT_PULLUP);
  pinMode(switch12, INPUT_PULLUP);

   pinMode(vibrationMotor, OUTPUT);   // Imposta il pin del motore come output
  digitalWrite(vibrationMotor, LOW); // Inizialmente spegne il motore

  // Inizializzazione tastiera e consumer
  Keyboard.begin();
  Consumer.begin();
}

void loop() {
  // Leggi lo stato attuale di ciascun tasto
  switchState[0] = !digitalRead(switch1);
  switchState[1] = !digitalRead(switch2);
  switchState[2] = !digitalRead(switch3);
  switchState[3] = !digitalRead(switch4);
  switchState[4] = !digitalRead(switch5);
  switchState[5] = !digitalRead(switch6);
  switchState[6] = !digitalRead(switch7);
  switchState[7] = !digitalRead(switch8);
  switchState[8] = !digitalRead(switch9);
  switchState[9] = !digitalRead(switch10);
  switchState[10] = !digitalRead(switch11);
  switchState[11] = !digitalRead(switch12);

  // Variabile per tracciare se un tasto è stato appena premuto
  bool keyPressed = false;

  for (int i = 0; i < 12; i++) {
    if (switchState[i] && !prevSwitchState[i]) {
      // Il tasto è stato appena premuto
      switch (i) {
        case 0: Keyboard.press('r'); break;
        case 1: Keyboard.press('e'); break;
        case 2: Keyboard.press('w'); break;
        case 3: Keyboard.press('q'); break;
        case 4: Keyboard.press('f'); break;
        case 5: Keyboard.press('d'); break;
        case 6: Keyboard.press('s'); break;
        case 7: Keyboard.press('a'); break;
        case 8: Keyboard.press('v'); break;
        case 9: Keyboard.press('c'); break;
        case 10: Keyboard.press('x'); break;
        case 11: Keyboard.press('z'); break;
      }
      keyPressed = true;
      Keyboard.releaseAll();  // Rilascia tutti i tasti
    }

      // Se il tasto è ancora premuto, mantieni il motore di vibrazione acceso
    if (switchState[i]) {
       keyPressed = true;  // Continua a vibrare se un tasto è ancora premuto
    }

    // Aggiorna lo stato precedente
    prevSwitchState[i] = switchState[i];
  }
```

```
  // Se un tasto è stato premuto, aggiorna il timer di inattività
  if (keyPressed) {
    lastKeyPressTime = millis(); // Resetta il timer di inattività
    digitalWrite(vibrationMotor, HIGH); // Mantiene il motore di vibrazione acceso
  } else {
    digitalWrite(vibrationMotor, LOW);  // Spegne il motore di vibrazione
  }

  // Controlla se è passato il tempo di inattività
  if (millis() - lastKeyPressTime >= inactivityTimeout) {
    // Sequenza di vibrazione (5 vibrazioni brevi)
    for (int i = 0; i < 5; i++) {
      digitalWrite(vibrationMotor, HIGH); // Vibrazione ON
      delay(200); // 200 ms
      digitalWrite(vibrationMotor, LOW);  // Vibrazione OFF
      delay(200); // 200 ms
    }
    lastKeyPressTime = millis(); // Resetta il timer di inattività dopo la vibrazione
  }

  delay(10);  // Piccola pausa per evitare letture multiple
}
```

Concept 4 - Rhythmic keys

```
#include <Keyboard.h>

// Definizione dei pin delle righe
const int rowPins[3] = {2, 3, 4};

// Definizione dei pin delle colonne
const int colPins[4] = {5, 6, 7, 8};

// Definizione della mappatura dei tasti
char keymap[3][4] = {
  {'P', 'O', 'I', 'U'},
  {'L', 'K', 'J', 'H'},
  {'M', 'N', 'B', 'V'}
};

// Stato precedente dei tasti
bool previousState[3][4];

// Definizione del pin del buzzer
const int buzzerPin = 10;

// Set di frequenze armoniose più alte per suoni più udibili
const int metronomeFrequencies[] = {500, 600, 700, 800, 900, 1000}; // Frequenze più alte per volume maggiore
const int numFrequencies = sizeof(metronomeFrequencies) / sizeof(metronomeFrequencies[0]); // Numero di frequenze

// Variabili per il rilevamento della pressione prolungata
unsigned long pressStartTime[3][4];  // Tempo in cui il tasto è stato premuto
bool longPressDetected[3][4];       // Flag per rilevare la pressione prolungata
bool keyPressedOnce[3][4];          // Flag per registrare la pressione singola del tasto

// Variabili per il timeout di inattività
unsigned long lastKeyPressTime = 0;   // Tempo dell'ultima pressione di un tasto
const unsigned long inactivityThreshold = 5000;  // Tempo di inattività (5 secondi)
bool inactivityAlarmActive = false;   // Flag per indicare se l'allarme è attivo
unsigned long inactivityStart = 0;    // Tempo di inizio del suono di inattività
bool inactivitySoundPlaying = false;  // Flag per indicare se il suono di inattività è in corso
int inactivityBeepCount = 0;          // Contatore per i beep di inattività
const int beepDuration = 200;         // Durata di ogni beep in millisecondi
const int beepInterval = 300;         // Intervallo tra i beep in millisecondi

void setup() {
  // Inizializza le righe come output e impostale a HIGH
  for (int row = 0; row < 3; row++) {
    pinMode(rowPins[row], OUTPUT);
    digitalWrite(rowPins[row], HIGH);
  }

  // Inizializza le colonne come input pullup
  for (int col = 0; col < 4; col++) {
    pinMode(colPins[col], INPUT_PULLUP);
  }

  // Inizializza lo stato precedente dei tasti e altre variabili
  for (int row = 0; row < 3; row++) {
    for (int col = 0; col < 4; col++) {
      previousState[row][col] = HIGH; // Assume che nessun tasto sia premuto all'inizio
      pressStartTime[row][col] = 0;
      longPressDetected[row][col] = false;
      keyPressedOnce[row][col] = false;  // Inizializza il flag a "non premuto"
    }
  }

  // Inizializza la comunicazione seriale per il debug
  Serial.begin(9600);

  // Inizializza la tastiera
  Keyboard.begin();

  // Inizializza il buzzer
  pinMode(buzzerPin, OUTPUT);
  noTone(buzzerPin);  // Assicurati che il buzzer sia spento all'inizio

  // Imposta il tempo iniziale
  lastKeyPressTime = millis();
}

void loop() {
  bool anyKeyPressed = false; // Variabile per rilevare se un qualsiasi tasto è stato premuto

  // Verifica se un allarme di inattività è attivo
  if (inactivitySoundPlaying) {
    // Se l'inattività è attiva, suona il buzzer 5 volte con un intervallo tra i suoni
    if (inactivityBeepCount < 5) {
      if (millis() - inactivityStart >= beepInterval) {
        tone(buzzerPin, 600, beepDuration);  // Suona il buzzer per 'beepDuration' ms
        inactivityStart = millis();  // Reset dell'inizio per l'intervallo tra i beep
        inactivityBeepCount++;  // Incrementa il contatore dei beep
      }
    } else {
      // Dopo aver suonato 5 volte, ferma il suono
      noTone(buzzerPin);
      inactivitySoundPlaying = false;  // Disattiva il flag
      inactivityAlarmActive = true;    // L'allarme è già stato suonato
    }
    return;  // Non permettiamo altre operazioni durante il suono di inattività
  }

  for (int row = 0; row < 3; row++) {
    // Imposta tutte le righe a HIGH
    for (int r = 0; r < 3; r++) {
      digitalWrite(rowPins[r], HIGH);
    }

    // Imposta la riga corrente a LOW per leggere i tasti di quella riga
    digitalWrite(rowPins[row], LOW);
    delayMicroseconds(5); // Piccolo ritardo per stabilizzare il segnale

    for (int col = 0; col < 4; col++) {
      // Leggi lo stato del tasto
      bool keyState = digitalRead(colPins[col]);

      // Aggiungi un breve ritardo per il debouncing
      delay(10);

      // Se lo stato del tasto è cambiato
      if (keyState != previousState[row][col]) {
        previousState[row][col] = keyState;

        if (keyState == LOW) {
          // Il tasto è appena stato premuto
          anyKeyPressed = true; // Segnala che un tasto è stato premuto
          pressStartTime[row][col] = millis();  // Inizia a contare il tempo
          longPressDetected[row][col] = false;
          keyPressedOnce[row][col] = false;  // Reset del flag quando il tasto viene premuto

          // Invia il carattere alla tastiera subito solo la prima volta
          if (!keyPressedOnce[row][col]) {
            keyPressedOnce[row][col] = true;  // Impedisce di inviare di nuovo la lettera
            if (keymap[row][col] != ' ') {
              Keyboard.press(keymap[row][col]);
              Serial.print("Premuto tasto: ");
              Serial.println(keymap[row][col]);
            } else {
              Keyboard.press(' ');
              Serial.println("Premuto tasto: Spazio");
            }
          }

          // Suona il buzzer con una frequenza casuale (durata breve per il feedback iniziale)
            int randomIndex = random(0, numFrequencies); // Scegli una frequenza casuale dall'array
          int randomFrequency = metronomeFrequencies[randomIndex];
            tone(buzzerPin, randomFrequency, 200);  // Emetti un suono breve (200 ms) per feedback iniziale

          // Reset del timer di inattività
          lastKeyPressTime = millis();  // Aggiorna il tempo dell'ultima pressione
          inactivityAlarmActive = false;  // Disattiva l'allarme di inattività se attivo
        } else {
          // Il tasto è rilasciato
          if (keymap[row][col] != ' ') {
            Keyboard.release(keymap[row][col]);
            Serial.print("Rilasciato tasto: ");
            Serial.println(keymap[row][col]);
          } else {
            Keyboard.release(' ');
            Serial.println("Rilasciato tasto: Spazio");
          }
          noTone(buzzerPin);  // Spegni il buzzer
          longPressDetected[row][col] = false;
          keyPressedOnce[row][col] = false;  // Reset del flag al rilascio
        }
      }

      // Controlla se il pulsante è stato tenuto premuto a lungo
      if (keyState == LOW && millis() - pressStartTime[row][col] > 1000) {
        // Se il pulsante è tenuto premuto per più di 1000 ms (1 secondo)
        longPressDetected[row][col] = true;

        // Emetti suoni intermittenti come feedback
        if ((millis() / 500) % 2 == 0) {  // Cambia stato ogni 500 ms
          tone(buzzerPin, 700);  // Suona il buzzer
        } else {
          noTone(buzzerPin);  // Spegni il buzzer
        }
      }
    }
```

```
    // Riporta la riga corrente a HIGH
    digitalWrite(rowPins[row], HIGH);
    delayMicroseconds(5); // Aggiungi un piccolo ritardo per stabilizzare il segnale
  }

  // Controlla se è passato il tempo di inattività (5 secondi)
  if (!anyKeyPressed && (millis() - lastKeyPressTime > inactivityThreshold)) {
    if (!inactivityAlarmActive) {
      // Se sono trascorsi più di 5 secondi senza alcuna pressione, avvia il suono di inattività
      inactivityBeepCount = 0;  // Reset del contatore dei beep
      inactivityStart = millis();  // Inizia a contare il tempo per il primo beep
      inactivitySoundPlaying = true;  // Attiva il suono di inattività
      Serial.println("Nessuna pressione rilevata per 5 secondi. Allarme suonato.");
    }
  }

  // Se nessun tasto è premuto, spegni il buzzer
  if (!anyKeyPressed) {
    noTone(buzzerPin);  // Assicurati che il buzzer sia spento
  }

  delay(10); // Aggiungi un piccolo ritardo per debouncing
}
```


Next possible letters feature

```
#include <Keyboard.h>

// Definizione dei pin delle righe per i tasti
const int rowPins[3] = {2, 3, 4};

// Definizione dei pin delle colonne per i tasti
const int colPins[4] = {5, 6, 7, 8};

// Definizione dei pin delle righe per i LED (positivi)
const int ledRowPins[3] = {15, A1, A2};

// Definizione dei pin delle colonne per i LED (negativi)
const int ledColPins[4] = {9, 10, 16, 14};

// Definizione della mappatura dei tasti e dei LED
char keymap[3][4] = {
  {‘R’, ‘E’, ‘W’, ‘Q’},  // Mappiamo “Q” come barra spaziatrice
  {‘F’, ‘D’, ‘S’, ‘A’},
  {‘V’, ‘C’, ‘X’, ‘Z’}
};

// Mappatura completa basata sulle lettere successive nell’alfabeto inglese
char possibleNextLetters[26][26] = {
  {‘B’, ‘C’, ‘D’, ‘E’, ‘F’, ‘G’, ‘H’, ‘I’, ‘K’, ‘L’, ‘M’, ‘N’, ‘P’, ‘Q’, ‘R’, ‘S’, ‘T’, ‘U’, ‘V’, ‘W’, ‘X’, ‘Y’, ‘Z’}, // A
  {‘A’, ‘E’, ‘I’, ‘L’, ‘O’, ‘R’, ‘U’}, // B
  {‘A’, ‘E’, ‘H’, ‘I’, ‘K’, ‘L’, ‘O’, ‘R’, ‘T’, ‘U’, ‘Y’}, // C
  {‘A’, ‘E’, ‘G’, ‘I’, ‘L’, ‘O’, ‘R’, ‘U’, ‘W’}, // D
  {‘A’, ‘B’, ‘C’, ‘D’, ‘E’, ‘F’, ‘G’, ‘H’, ‘I’, ‘J’, ‘K’, ‘L’, ‘M’, ‘N’, ‘O’, ‘P’, ‘Q’, ‘R’, ‘S’, ‘T’, ‘U’, ‘V’, ‘W’, ‘X’, ‘Y’, ‘Z’}, // E
  {‘A’, ‘E’, ‘I’, ‘L’, ‘O’, ‘R’, ‘U’}, // F
  {‘A’, ‘E’, ‘G’, ‘H’, ‘I’, ‘L’, ‘N’, ‘O’, ‘R’, ‘U’}, // G
  {‘A’, ‘E’, ‘I’, ‘O’, ‘R’, ‘U’, ‘Y’}, // H
  {‘A’, ‘B’, ‘C’, ‘D’, ‘E’, ‘F’, ‘G’, ‘H’, ‘I’, ‘J’, ‘K’, ‘L’, ‘M’, ‘N’, ‘O’, ‘P’, ‘Q’, ‘R’, ‘S’, ‘T’, ‘U’, ‘V’, ‘W’, ‘X’, ‘Y’, ‘Z’}, // I
  {‘A’, ‘E’, ‘I’, ‘O’, ‘U’}, // J
  {‘A’, ‘E’, ‘I’, ‘N’, ‘O’, ‘R’, ‘S’, ‘U’}, // K
  {‘A’, ‘E’, ‘F’, ‘I’, ‘L’, ‘O’, ‘R’, ‘T’, ‘U’, ‘V’, ‘Y’}, // L
  {‘A’, ‘E’, ‘I’, ‘M’, ‘N’, ‘O’, ‘P’, ‘U’, ‘Y’}, // M
  {‘A’, ‘D’, ‘E’, ‘G’, ‘I’, ‘K’, ‘L’, ‘O’, ‘S’, ‘T’, ‘U’, ‘Y’}, // N
  {‘A’, ‘B’, ‘C’, ‘D’, ‘E’, ‘F’, ‘G’, ‘H’, ‘I’, ‘K’, ‘L’, ‘M’, ‘N’, ‘O’, ‘P’, ‘Q’, ‘R’, ‘S’, ‘T’, ‘U’, ‘V’, ‘W’, ‘X’, ‘Y’, ‘Z’}, // O
  {‘A’, ‘E’, ‘H’, ‘I’, ‘L’, ‘O’, ‘R’, ‘S’, ‘T’, ‘U’, ‘Y’}, // P
  {‘U’}, // Q
  {‘A’, ‘D’, ‘E’, ‘G’, ‘H’, ‘I’, ‘K’, ‘L’, ‘N’, ‘O’, ‘R’, ‘S’, ‘T’, ‘U’, ‘V’, ‘W’, ‘Y’}, // R
  {‘A’, ‘C’, ‘E’, ‘H’, ‘I’, ‘K’, ‘L’, ‘M’, ‘N’, ‘O’, ‘P’, ‘Q’, ‘T’, ‘U’, ‘W’, ‘Y’}, // S
  {‘A’, ‘E’, ‘H’, ‘I’, ‘L’, ‘O’, ‘R’, ‘S’, ‘T’, ‘U’, ‘W’, ‘Y’}, // T
  {‘A’, ‘B’, ‘C’, ‘D’, ‘E’, ‘F’, ‘G’, ‘I’, ‘K’, ‘L’, ‘M’, ‘N’, ‘O’, ‘P’, ‘Q’, ‘R’, ‘S’, ‘T’, ‘V’, ‘X’, ‘Y’, ‘Z’}, // U
  {‘A’, ‘E’, ‘I’, ‘O’}, // V
  {‘A’, ‘E’, ‘H’, ‘I’, ‘L’, ‘N’, ‘O’, ‘R’}, // W
  {‘A’, ‘C’, ‘E’, ‘H’, ‘I’, ‘L’, ‘O’, ‘P’, ‘S’, ‘T’, ‘U’}, // X
  {‘A’, ‘E’, ‘I’, ‘O’, ‘U’}, // Y
  {‘A’, ‘E’, ‘I’, ‘O’, ‘U’}  // Z
};

// Stato precedente dei tasti
bool previousState[3][4];
bool activeLetters[3][4]; // Stato attivo dei LED delle lettere

void setup() {
  // Inizializza le righe come output e impostale a HIGH
  for (int row = 0; row < 3; row++) {
    pinMode(rowPins[row], OUTPUT);
    digitalWrite(rowPins[row], HIGH);
  }

  // Inizializza le colonne come input pullup
  for (int col = 0; col < 4; col++) {
    pinMode(colPins[col], INPUT_PULLUP);
  }

  // Inizializza i pin delle righe e delle colonne dei LED come output
  for (int row = 0; row < 3; row++) {
    pinMode(ledRowPins[row], OUTPUT);
    digitalWrite(ledRowPins[row], LOW); // Inizializza le righe LED a LOW (spenti)
  }

  for (int col = 0; col < 4; col++) {
    pinMode(ledColPins[col], OUTPUT);
    digitalWrite(ledColPins[col], HIGH); // Inizializza le colonne LED a HIGH (spenti)
  }

  // Inizializza lo stato precedente dei tasti e lo stato attivo dei LED
  for (int row = 0; row < 3; row++) {
    for (int col = 0; col < 4; col++) {
      previousState[row][col] = HIGH;
      activeLetters[row][col] = false; // Tutti i LED iniziano spenti
    }
  }

  // Inizializza la comunicazione seriale per il debug
  Serial.begin(9600);

  Keyboard.begin();
}

void loop() {
  for (int row = 0; row < 3; row++) {
    // Imposta tutte le righe a HIGH
    for (int r = 0; r < 3; r++) {
      digitalWrite(rowPins[r], HIGH);
    }

    // Imposta la riga corrente a LOW
    digitalWrite(rowPins[row], LOW);
    delayMicroseconds(5); // Piccolo ritardo per stabilizzare il segnale

    for (int col = 0; col < 4; col++) {
      // Leggi lo stato del tasto
      bool keyState = digitalRead(colPins[col]);

      // Se lo stato del tasto è cambiato
      if (keyState != previousState[row][col]) {
        previousState[row][col] = keyState;

        if (keyState == LOW) { // Tasto premuto
          char currentKey = keymap[row][col];

          if (currentKey == ‘Q’) {
            Keyboard.press(‘ ’);
            Serial.println(“Premuto tasto: Barra spaziatrice”);
          } else {
            Keyboard.press(currentKey);
            Serial.print(“Premuto tasto: ”);
            Serial.println(currentKey);
          }

          // Spegni tutti i LED precedenti
          for (int r = 0; r < 3; r++) {
            for (int c = 0; c < 4; c++) {
              if (activeLetters[r][c]) {
                digitalWrite(ledRowPins[r], LOW);
                digitalWrite(ledColPins[c], HIGH);
                activeLetters[r][c] = false;
              }
            }
          }

          // Accendi il LED della lettera premuta
          digitalWrite(ledRowPins[row], HIGH);
          digitalWrite(ledColPins[col], LOW);
          activeLetters[row][col] = true;

          // Accendi i LED delle lettere possibili successive
          int keyIndex = currentKey - ‘A’; // Calcola l’indice della lettera nell’alfabeto
          for (int r = 0; r < 3; r++) {
            for (int c = 0; c < 4; c++) {
              for (int k = 0; k < 26; k++) {
                if (possibleNextLetters[keyIndex][k] == keymap[r][c]) {
                  digitalWrite(ledRowPins[r], HIGH);
                  digitalWrite(ledColPins[c], LOW);
                  activeLetters[r][c] = true; // Mantieni acceso il LED
                }
              }
            }
          }
        } else { // Tasto rilasciato
          char currentKey = keymap[row][col];
          if (currentKey == ‘Q’) {
            Keyboard.release(‘ ’);
          } else {
            Keyboard.release(currentKey);
          }
          Serial.print(“Rilasciato tasto: ”);
          Serial.println(currentKey);
        }
      }
    }

    // Riporta la riga corrente a HIGH
    digitalWrite(rowPins[row], HIGH);
    delayMicroseconds(5); // Aggiungi un piccolo ritardo per stabilizzare il segnale
  }

  delay(10); // Aggiungi un piccolo ritardo per debouncing
}
```

Appendix F

Presentation for focus group.

10 MINUTES **Presentation**

30 MINUTES **Feedback**

Alessandra Galli

TYPE IT DOWN

Enhancing computer keyboards
for people with Parkinson's Disease.

Chair **Marco Rozendaal**
Mentor **Gert Pasman**
Mentor **Erik Prinsen**

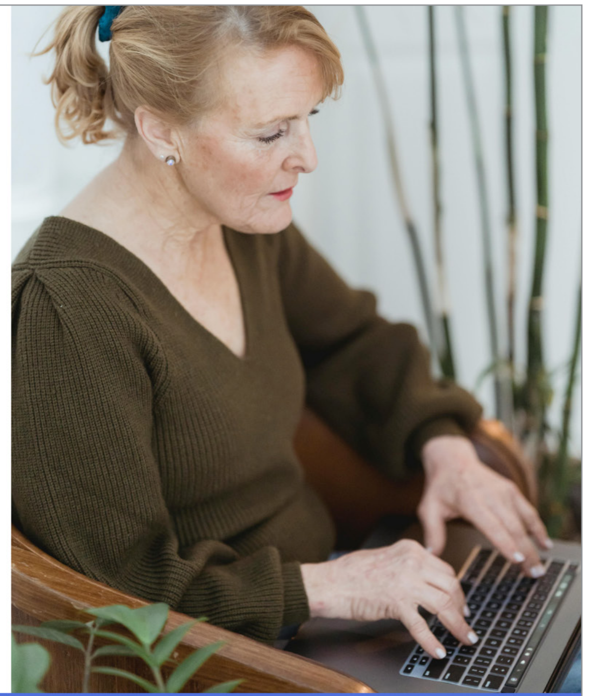
Student number 5617154

Alessandra Galli

+ Time
+ Tired and Frustrated
+ Mistakes

Computer **keyboard can be perceived as a barrier for users with Parkinson's Disease**, hindering their ability to complete tasks.

*This leads to feelings of **frustration**, avoidance tendencies, and reduced engagement in both professional and personal activities.*



Current problem

Alessandra Galli

I'm Alessandra, nice to meet you!

- Bachelor in product design, Milan
- Product manager at TheFabLab for 3 years, Milan
- Master's Integrated product Design, Delft
  Internship at UNStudio, Amsterdam

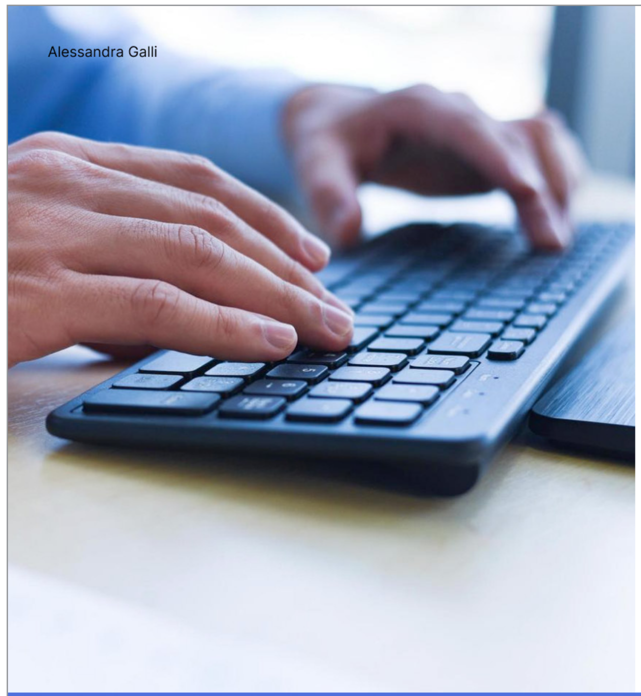
Alessandra Galli

This initiative seeks to improve quality of life and **EMPOWER INDIVIDUALS**.

This project aims to enhance computer keyboard interaction for people with Parkinson's disease, specifically addressing the symptom of **BRADYKINESIA**.

Project's aim

Alessandra Galli



"**Slowness of initiation of voluntary movement with progressive reduction in speed and amplitude of repetitive actions**"

Known in motor physiology as the sequence effect.

Bradykinesia

Alessandra Galli

Cueing techniques

*"Cueing can be defined as using **external stimuli** which provided temporal (related to time) or spatial (related to space) information to facilitate movement initiation and continuation".*

example of product with cueing technique integration

HOW ?

Alessandra Galli

VISUAL CUEING

Visual cueing uses visual stimuli like lines on the floor to guide movement and mitigate freezing episodes.

AUDITORY CUEING

Auditory cueing employs rhythmic auditory cues, such as metronome beats or music, to synchronise movements and improve gait patterns in those experiencing motor difficulties.

Cueing techniques

Alessandra Galli

VISUAL CUEING

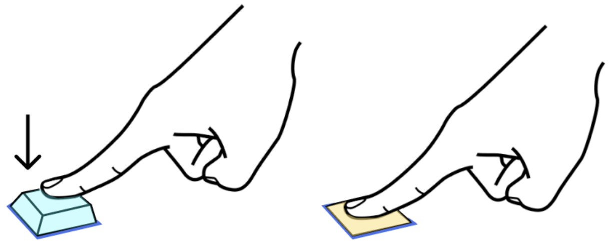
Visual cueing uses visual stimuli like lines on the floor to guide movement and mitigate freezing episodes.

Visual cueing

Alessandra Galli

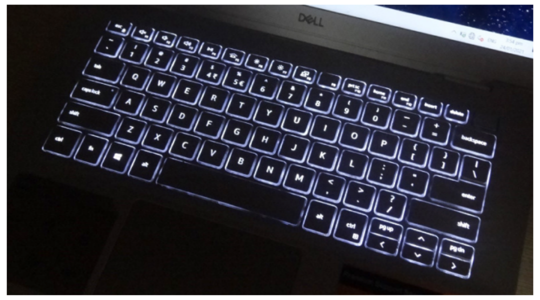
BASIC FEATURE

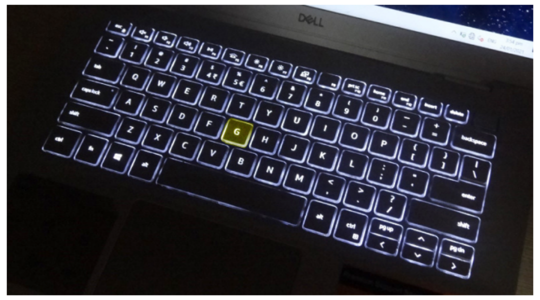
the key changes colour when pressed.



PROS
Enhances focus on typing
Provides visual feedback

CONS
Not visible in a bright room





Visual cueing

Alessandra Galli

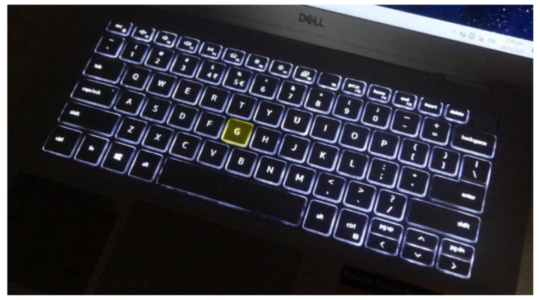
LANGUAGE STRUCTURE FEATURE

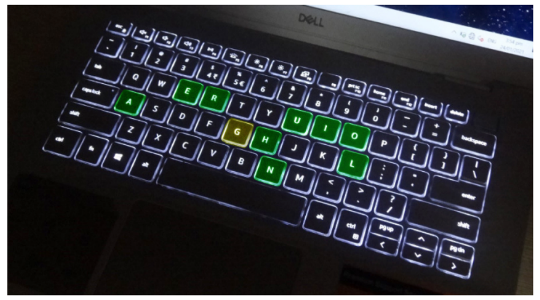
To assist people with Parkinson's in using a keyboard, implementing a lighting system that highlights the letters that can follow a given letter according to the rules of the English language is helpful.

G ⟶ **A, E, R, H, U, I, O, L, N**

PROS
Enhances focus on typing
Provides visual feedback
Reduce time required

CONS
Not visible in a bright room
Not 100% reliable



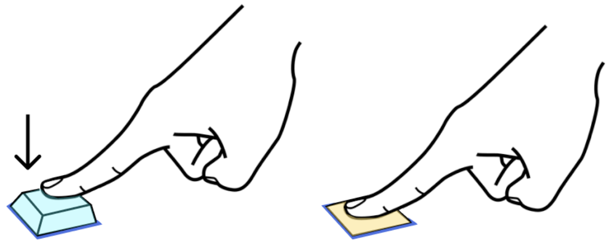


Visual cueing

Alessandra Galli

BASIC FEATURE

The key changes colour when pressed.



PROS
Enhances focus on typing
Provides visual feedback

CONS
Not visible in a bright room

Visual cueing

Alessandra Galli

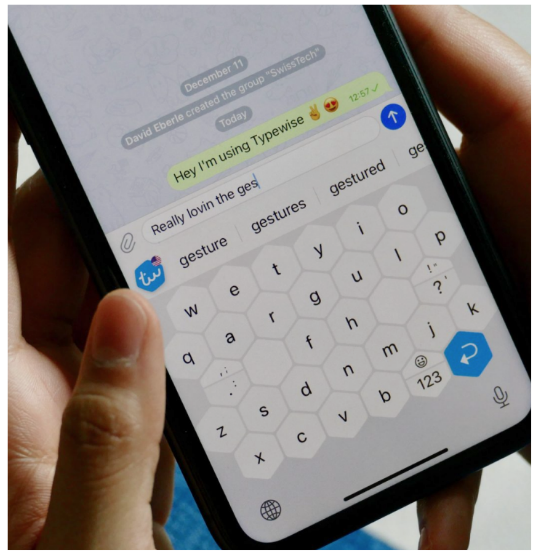
WORDS FEATURE

Keyboard with "text prediction technology".
AI algorithms which suggest what words users want to type.

⟶ touch screen

⟶ mechanical keyboard

PROS
Enhances focus on typing
Provides visual feedback
Reduce time required
Machine learning approach



Visual cueing

Alessandra Galli

AUDITORY CUEING

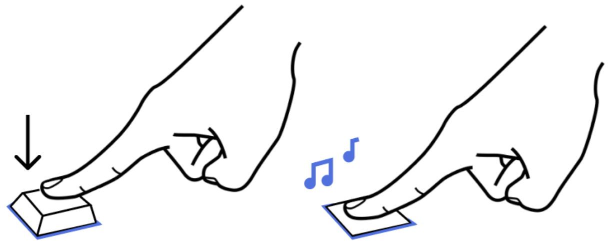
Auditory cueing employs rhythmic auditory cues, such as metronome beats or music, to synchronise movements and improve gait patterns in those experiencing motor difficulties.

Auditory cueing

Alessandra Galli

SOUND FEATURE

The key generated a sound when pressed. Different sounds can be associate to different keys (es. the sound of letters is different from the sound generated from keys with numbers).



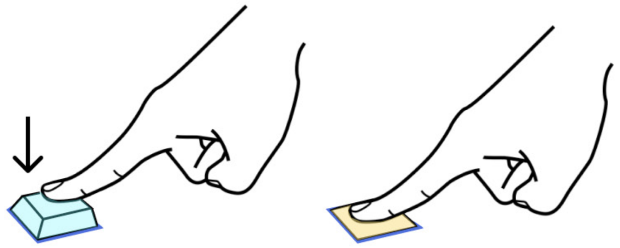
PROS
Enhances focus on typing
Provides sound feedback based on different key function

CONS
Loud switches could be enough as sound feedback

Auditory cueing

1 *BASIC FEATURE*

The key changes colour when pressed.
De toets verandert van kleur wanneer deze wordt ingedrukt.



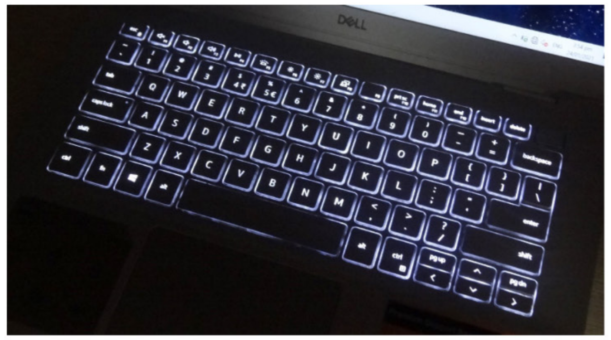
PROS

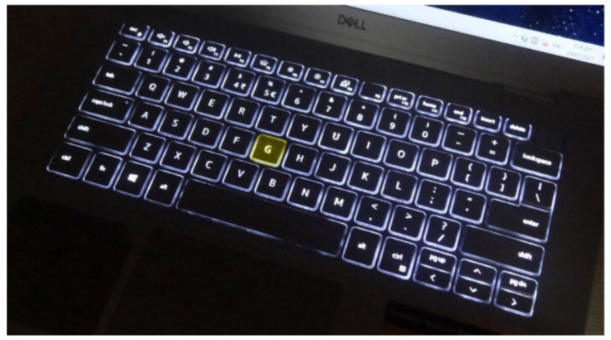
Enhances focus on typing
Verbetert de focus op typen

Provides visual feedback
Geeft visuele feedback

CONS

Not visible in a bright room
Niet zichtbaar in een heldere kamer





1. Do you think this feature could improve your interaction with the computer keyboard? Why?
Denk je dat deze functie je interactie met het computertoetsenbord zou kunnen verbeteren? Waarom?

2. How does it make you feel?
Hoe voel je je erbij?

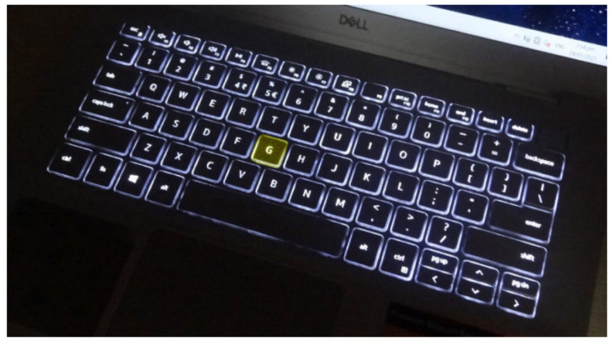
3. Do you see any other opportunities related to this feature?
Zie je andere mogelijkheden die gerelateerd zijn aan deze functie?

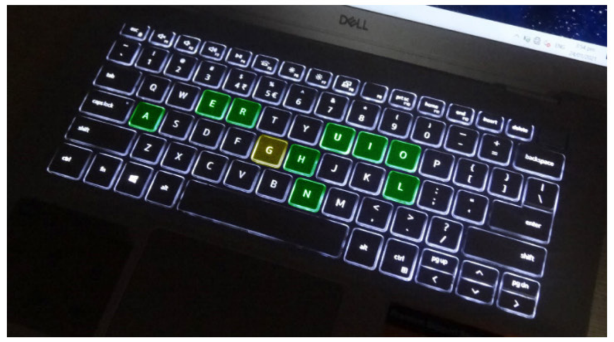
COLOURS SHOULD BE BRIGHT, BUT I LIKE IT AS CUEING

2 LANGUAGE STRUCTURE FEATURE

To assist people with Parkinson's in using a keyboard, implementing a lighting system that highlights the letters that can follow a given letter according to the rules of the English language is helpful.
Om mensen met de ziekte van Parkinson te helpen bij het gebruik van een toetsenbord, is het nuttig om een verlichtingssysteem te implementeren dat de letters markeert die volgens de regels van de Engelse taal op een gegeven letter kunnen volgen.

G → **A, E, R, H, U, I, O, L, N**





PROS

Enhances focus on typing
Verbetert de focus op typen

Provides visual feedback
Geeft visuele feedback

Reduce time required
Vermindert de benodigde tijd

CONS

Not visible in a bright room
Niet zichtbaar in een heldere kamer

Not 100% reliable
Niet 100% betrouwbaar

1. Do you think this feature could improve your interaction with the computer keyboard? Why?
Denk je dat deze functie je interactie met het computertoetsenbord zou kunnen verbeteren? Waarom?

2. How does it make you feel?
Hoe voel je je erbij?

3. Do you see any other opportunities related to this feature?
Zie je andere mogelijkheden die gerelateerd zijn aan deze functie?

EASY WAY TO SWITCH FROM ENGLISH TO DUTCH

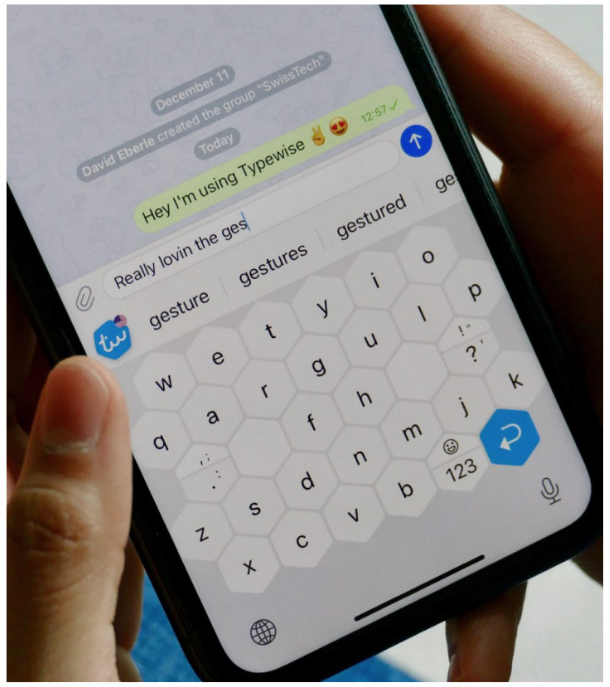
I LIKE THE SECOND IDEA. IT IS IMPORTANT TO BE ABLE TO DEACTIVATE IT QUICKLY

3 WORDS FEATURE

Keyboard with "text prediction technology".
AI algorithms which suggest what words users want to type.
Toetsenbord met "tekstvoorspellingstechnologie".
AI-algoritmen die suggereren welke woorden gebruikers willen typen.

→ touch screen

→ mechanical keyboard



PROS

Enhances focus on typing
Verbetert de focus op typen

Provides visual feedback
Geeft visuele feedback

CONS

Reduce time required
Vermindert de benodigde tijd

Machine learning approach
Machine learning benadering

1. Do you think this feature could improve your interaction with the computer keyboard? Why?
Denk je dat deze functie je interactie met het computertoetsenbord zou kunnen verbeteren? Waarom?

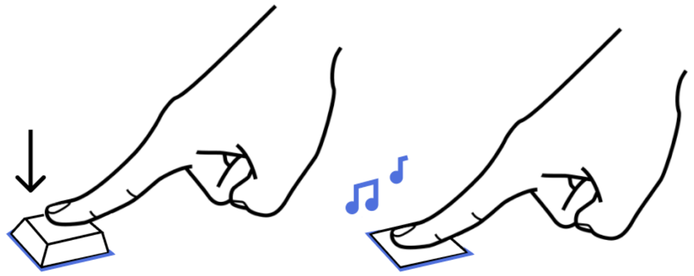
2. How does it make you feel?
Hoe voel je je erbij?

3. Do you see any other opportunities related to this feature?
Zie je andere mogelijkheden die gerelateerd zijn aan deze functie?

I LIKE THE THIRD IDEA, IT IS LIKE OUTLOOK. I WANT TO PRESS THE SPACE BAR TO SELECT THE RIGHT WORD.

4 SOUND FEATURE

The key generated a sound when pressed. Different sounds can be associate to different keys (es. the sound of letters is different from the sound generated from keys with numbers).
De toets genereerde een geluid wanneer deze werd ingedrukt. Verschillende geluiden kunnen aan verschillende toetsen worden gekoppeld (bijv. het geluid van letters is anders dan het geluid van toetsen met nummers).



PROS

Enhances focus on typing
Verbetert de focus op typen

Provides sound feedback based on different key function
Geeft geluidsfeedback op basis van verschillende toetsfuncties

CONS

Loud switches could be sufficient as sound feedback.
Luidruchtige schakelaars kunnen voldoende zijn als geluidsfeedback.

1. Do you think this feature could improve your interaction with the computer keyboard? Why?
Denk je dat deze functie je interactie met het computertoetsenbord zou kunnen verbeteren? Waarom?

2. How does it make you feel?
Hoe voel je je erbij?

3. Do you see any other opportunities related to this feature?
Zie je andere mogelijkheden die gerelateerd zijn aan deze functie?

4. Do you think sound feedback would make typing easier or more enjoyable for you?
Denk je dat geluidsfeedback het typen gemakkelijker of leuker voor je zou maken?

NO SOUND, EVERYONE AGREES. THE THINK IT MIGHT BE ANNOYING.

ADDITIONAL FEEDBACK

Do you think that haptic feedback (vibration) could be useful?
Denk je dat haptische feedback (trilling) nuttig kan zijn?

Do you have any other ideas on how to improve your experience while using a computer keyboard?
Zijn er andere ideeën over hoe je jouw ervaring met het gebruik van een computer toetsenbord kunt verbeteren?

YES, HAPTIC FEEDBACK COULD BE USEFUL. EVERYONE HAS TREMORS, EVEN IF THEY ARE NOT VISIBLE.

PRESS THE KEY AND GET VIBRATION, IT COULD BE GOOD.

TO AVOID BEING STUCK ON A KEY, YOU PRESS THE KEY AND AFTER A FEW SECONDS GOES BACK.

VIBRATION ON THE WRIST / PALM COULD BE USEFUL. COULD BE CLEVER TO HAVE SOMETHING LIKE THIS ONE

Appendix G

Keyboard test

Q W E R A S D F Z X C V	***Prototype 1*** *Standard keyboard*	***60 sec X-test*** **1A** Repetitively tap the key "x" as fast as possible with your left hand. **1B** Repetitively tap the key "x" as fast as possible with your right hand.	***60 sec WE-test*** **1C** Alternate between tapping the keys "W" and "E" as fast as possible with your left hand. **1D** Alternate between tapping the keys "X" and "C" as fast as possible with your right hand.	***60 sec AF-test*** **1E** Alternate between tapping the keys "A" and "F" as fast as possible with your left hand. **1F** Alternate between tapping the keys "Q" and "R" as fast as possible with your right hand.
Q W E R A S D F Z X C V	***Prototype 2*** *Keyboard with vibrating palm rest*	***60 sec X-test*** **2A** Repetitively tap the key "x" as fast as possible with your left hand. **2B** Repetitively tap the key "x" as fast as possible with your right hand.	***60 sec WE-test*** **2C** Alternate between tapping the keys "W" and "E" as fast as possible with your left hand. **2D** Alternate between tapping the keys "W" and "E" as fast as possible with your right hand.	***60 sec AF-test*** **2E** Alternate between tapping the keys "A" and "F" as fast as possible with your left hand. **2F** Alternate between tapping the keys "A" and "F" as fast as possible with your right hand.
U I O P H J K L Y B N M	***Prototype 3*** *Keyboard with vibrating switches*	***60 sec U-test*** **3A** Repetitively tap the key "U" as fast as possible with your left hand. **3B** Repetitively tap the key "U" as fast as possible with your right hand.	***60 sec IO-test*** **3C** Alternate between tapping the keys "I" and "O" as fast as possible with your left hand. **3D** Alternate between tapping the keys "I" and "O" as fast as possible with your right hand.	***60 sec HL-test*** **3E** Alternate between tapping the keys "H" and "L" as fast as possible with your left hand. **3F** Alternate between tapping the keys "H" and "L" as fast as possible with your right hand.

Results

Prototype 1 *Standard keyboard*	***60 sec X-test*** User with PD: left dominant one, more fatigue and less control **1A** Repetitively tap the key "x" as fast as possible with your left hand. — User with PD **132**, User without PD **134** **1B** Repetitively tap the key "x" as fast as possible with your right hand. — User with PD **138**, User without PD **139**	***60 sec WE-test*** **1C** Alternate between tapping the keys "W" and "E" as fast as possible with your left hand. — User with PD **139**, User without PD **142** **1D** Alternate between tapping the keys "X" and "C" as fast as possible with your right hand. — User with PD **147**, User without PD **147**	***60 sec AF-test*** **1E** Alternate between tapping the keys "A" and "F" as fast as possible with your left hand. — User with PD **108**, User without PD **147** **1F** Alternate between tapping the keys "Q" and "R" as fast as possible with your right hand. — User with PD **107**, User without PD **147**
Prototype 2 *Keyboard with vibrating palm rest*	***60 sec X-test*** **2A** Repetitively tap the key "x" as fast as possible with your left hand. — User with PD **130**, User without PD **140** **2B** Repetitively tap the key "x" as fast as possible with your right hand. — User with PD **130**, User without PD **142** User with PD: this one better, more rhythm, felt less tired compared to the 1B	***60 sec WE-test*** **2C** Alternate between tapping the keys "W" and "E" as fast as possible with your left hand. — User with PD **142**, User without PD **149** **2D** Alternate between tapping the keys "W" and "E" as fast as possible with your right hand. — User with PD **149**, User without PD **145**	***60 sec AF-test*** **2E** Alternate between tapping the keys "A" and "F" as fast as possible with your left hand. — User with PD **108**, User without PD **146** **2F** Alternate between tapping the keys "A" and "F" as fast as possible with your right hand. — User with PD **105**, User without PD **147**
Prototype 3 *Keyboard with vibrating switches*	***60 sec U-test*** **3A** Repetitively tap the key "U" as fast as possible with your left hand. — User with PD **293**, User without PD **284** **3B** Repetitively tap the key "U" as fast as possible with your right hand. — User with PD **305**, User without PD **345**	***60 sec IO-test*** User with PD: more control, I cannot sense if the fingertips vibration helps. I believe the sound is more important than vibration. **3C** Alternate between tapping the keys "I" and "O" as fast as possible with your left hand. — User with PD **291**, User without PD **430** **3D** Alternate between tapping the keys "I" and "O" as fast as possible with your right hand. — User with PD **281**, User without PD **451**	***60 sec HL-test*** **3E** Alternate between tapping the keys "H" and "L" as fast as possible with your left hand. — User with PD **191**, User without PD **225** **3F** Alternate between tapping the keys "H" and "L" as fast as possible with your right hand. — User with PD **155**, User without PD **156**

Test user with PD:

1A: xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx (right)

1B: xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx (left)left dominant one, more fatigue and less control

1C: wwwweeeweweeeewwwwweeeeeeeeeewwewwweeewwwweeeewwewwewwww-wwwwwwwwwwwwwwwwwweweeweeeeewweeewwwwwwwwwwwewwwwwwww-weweeeeeeeeeweweeweweeeeeeeeeeweeweewe (right) more difficult that with just one key

1D: wwwewewweeeeewwwweeeeeeewewwwwwweeeewwewewewweeweeeeeeew-wewweeeweewwwweeeweeeweeeweeweewwewewewewewewewewwewewwewee-wewewewewewewwewewewew (left) no control, all over the place

1E: affffffffffffffffffffffffaaaaffffffffaaaaaaaaaaaaaffaaffaaaaffaaafffaaaaaaaaaffaaaf-faaffaaffaaaffaaaafff (right) (real test remove completely vibration motor because the sound is there) it seems easier than the two close keys because I used only one finger.

1F: afaaaaaaaafffffffffffffffffffffffffaaaaffffffffffffffffaaaaaaffaaasaaafffaaaaaaaafff-faaaaffffffffffffffff (left) (I clicked for mistake s and d).

2A: xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx (right) this one better, more rhythm, felt less tired compared to the 1A

2B: xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx (left one) more tired, less consistent even if I typed more keys compared to the 2A

2C: wewwweweeeeeewwwwweweeeewwwwweeeeeeeeeweeeeeeeeewewewwew-wwwwwwwweweewweweeeeeeeeeweeeeeeweewewewewewewweeeeeeeeeweee-weweeeeeeeeweweeeeeeeeeeeeeeeee (right hand) a bit better with vibration because the rhythm helps, but I still got tired

2D: wwweeweeeewwweweeweewweeeeweeweeeweeeewwewwewewwwewweeewee-weewweweewewewewewwewewwwewewwewweeweeeewewewewewewewwewwweee-weweeeweeweweeeeeeeewwee (left) this one was the worst so far, maybe it is because I'm getting tired.

2E: affffffffffffffffffffffaaaaffffffaaaaaaaaaaaaffaaafffaaaffaaaaaaaaaaaaaasfffaaaaffaaaf-faaaaaaaaaaaaaaaaa (right) what helped was not much vibration, but the sound

2F: afffffffffffffffffffffffffffffffffffffffffffffffffffafffffffffffffffffffaaaaasaaaaaaaaaaaaaas-ffffffffffffffffffa (left) it would be nice to have something more comfortable - be careful about ergonomics

3A: UU (right) it felt like a constasteis buzz

3B: OOO (left) no control, it helps if I need to type the same letter

3C: IOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOI-OIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOI-OIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOI-OIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOI (right) more control, I cannot sense if the fingertips vibration helps. I believe the sound is more important than vibration.

3D: IOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOOIOIOIOIOIOIOIOIOIOI-OIOIOIOIOIOIOIIOIOIOIIOIOIIOIOIOOOOIOIOIOIOIIIOIOIOIOIOIOIOIOIOIOIOOIOIOIOOIOIIOIOO-IOIOIIOIOIOIOIOOIIOIOIOIOIOIOIOOOIOIOIOOIOIOOOIIOIOIOOIOIOIIOOIOIOIOOIOIOIOIOOIOOO-IOOOIIIOIOIOIOOIOOIOIOIOIOIOOIOIOOIOIOOIIOOIIOIOOOIOIOIO (left) I was getting really slow. I did not feel any clue that was supporting me.

3E: HHHHHHHLJHHHHLHLHLHLHLHLHLJHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHL-HLJHLHJLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHJLHLHLHLHL-HLHLHLHLHLHLHLHLHLHLHLHLHLHLHLH (right) same, but I am also getting tired.

3F: HLHLJHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHL-HLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHL-HLHLHLHLHLHLHLHLHLHLJHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLHLJHLHLHL-HLH (left) larger movement goes better and also one finger movement.

HLHHLLLLLLLLLLLLLLLLPILJPPLJPLLJPLOPLLJPILJPLJPLLLLLJKPOJKPYNBKLLKJL-JLLLKLJKLKLKLKLKLLLLLLLLLLKKKLLKJJKIKOKKKKKKKKKKKKKKKLLKLLKKKKLLK-KKKKKKKKKKKKKKLKKJKKKLKKKKKKKLLLLKKKKKKKKKKKKKKKKKKKKKKKKKN-LLMMMMMMMMMMMMMKKKKKKKKKKK

- it is too long
- speed is not the issue.
- it is difficult to understand if it better on fingertips or palm. it would be nice to have also something on the wrist.

Test user without PD:

1A (left)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

1B (right)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

1C (left)
wweeewwewwweeeweewewewewewewewewewewweeewwewwwwqwwwwewewewweee-wwwwwwwwwwwwwwwewwwweeewewwwweeweewewewewewwwwwwwwwwwww-wewwwwwwewwwwwwewwwwwwewwwwwwe

1D (right)
wwwwwwewewweswewewsweeewwewwewwwewweeeewwwwewwweeeeeweeeeeeee-wweeweeeeewewwewwweeweewweeewwweewweeewwewewewwweeewwweewweew-weewwwwewwwwewewweewewwweew

1E (right)
aaffaafafafafaffafafafaaffafaafffaafaafffaaffffffaaaffafffafaafaffafafffffaafaaaaaffaafaaf-faaaaaaaaafffffffffafaafaafafafafafffffaaaafafafafffaaffaffaf

1F (left)
sssaaffaffaffafaafafffafffafaafafafffffffaafafaaafaaffffffafaafffaffaaafaffafafafaffaaffafafaa-faaafaaffafafafaffafaaaffffaaaffafaaffffaaffffaafaafaafaf

2A (left) lieve vibrazione, non è fastidiosa
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

2B (right)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

2C (left)
wweesweeweeeweewewweeeewewewewewewewewewewweeeewewewewweeewweeeeeeewewee-wewewwewewewewewweweewewewewewewewewwewewewewewewewewewewewewewewewewewee-wewwewwewwewewwewewwewwwe

2D (right)
weeeeeeeeeeewwewwewwewwweewewwewewewewweewewewewewewewwewewewewewew-wweewwwewewwweewwewwwewewewewwweewwewewwweweewwewewewwww-wewewewewewewewweewewewwwewewwewewwewwe

2E (left)
affaaafafaffafafffaffafafaaafffaaafaaffaaffafffafafafafffafffafaafffffafaaffafffffaaffffaafaafaff-faaafaaaffaafafaffaafafafafffafffffafafaafaffafafafaaafa

2F (right)
aafafafaafafaaaaafafafffafafafafafffaaffafafafafffafffaafffaafafafaffafafaffaaffafafafaffffafafafaffafa-faaffafffffaafafafafafafafffafafafafaffafaafafaafaafafaaaaafaf

3A (left) I prefer this one, it's like the smartphone vibration
UUU

3B (right)
UU

3C (left)
IOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOOIOIOIOIOIOIOIOIOIOIOIOIOI-OIOIOIOIOIOIOIOIOIOIOOIIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIIOIOIOIOIOIOIOIOIOO-IIOIOIOIOOIOIOIOIOIOIOOOOOOIOOOIOOIIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOOIOIOOIIOI-OIOIOOIOIOIOIOIOIOIOIOOIOIIOOIOIOIOIOIOIOIOIOIIOOIIOIOOIOIOIOIOOIIOOIOIOOIOIOOI-OIOIOOIOIOOOIIOOOIOOIOIOIOIIOIOIOIIOIOIOOIOOIOIOIOOOIOOIOIOIIOOOIOIOIOIIOOIOI-OIOIIOOOIOIOIOIOIOOOIOIOIOIOOIOIIO

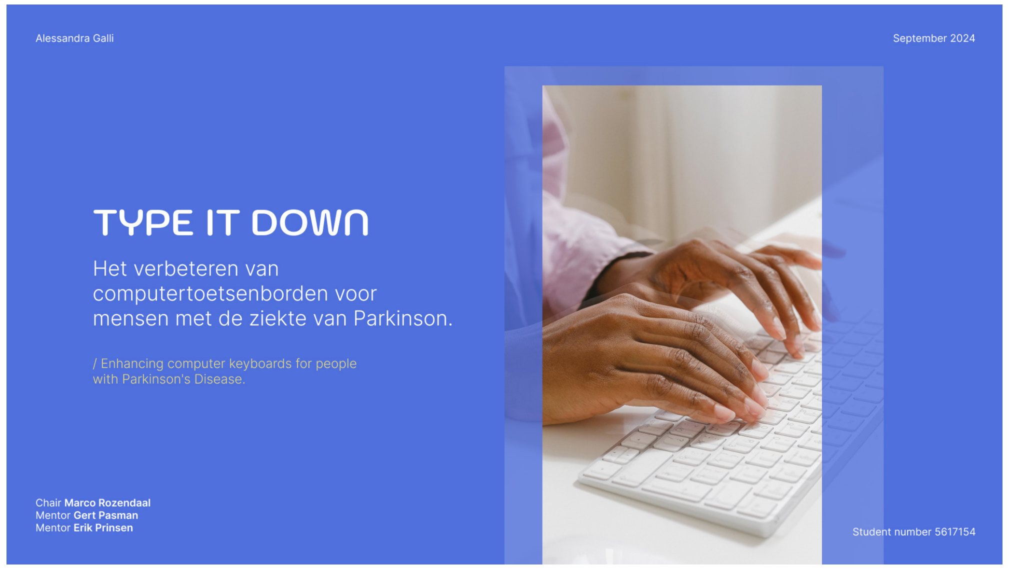
3D (right)
IIOIIIIOOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIIOIOIOIOIOIOIOIOIOIOIOI-OIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIIOIOIOIOIOI-OIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIIOIIIIOIOIIOIIOOIOIOIOIOIOIOIOIOIOIOIOIIIOIOI-OIIIOOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIOIIIOIOIOIIOIOIOIOIOII-OIOIOIOIOIOIOIOIOIOIIOIOIOIOIOIOIOIIIOIOIOIOIIOOIOIOIIOIIIOIIOOIOIOIOIIOIOIIOIIIOIIOII-OIOIOIOIOIOIIOIOIOIIIIIOIOOIII

3E (left)
HLHLLLLLLLHLLLLLLLLLLLLLLLLLLLLLLLLLHLLLLLLLLLLLLLLLHLHLLLLLLHLLHHLLLH-HLLLLLLLLLHLLHLLLLLLHLHLHHLLLHLLHLHLHLLLHLHLLLLHLLLLLLLLLLHLLLHHHLLLL-HLLHLHLLHLLLLLLLLLLLLLLLLHLLLLLLLLLLHLLLLLLHLLLLHLLLLLLHLLLLLLLLLLLLLLLLLLLL LLLLLLLLLLLLLLLLLHL

3F (right)
LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLHLHLLLHLLHLHLHLLLHLHLL-HLLLLLLLLLLLLLLLLLLLLLLLHLLLLLLHLLLLLLLLLLLLLLLLLLLLLLLLHLLHLLLHLLLLLHLHLLL-HLLLLLHLLLLLLLLLLLLHLHLLLLL

Appendix H

Presentation for focus group.



Alessandra Galli

September 2024

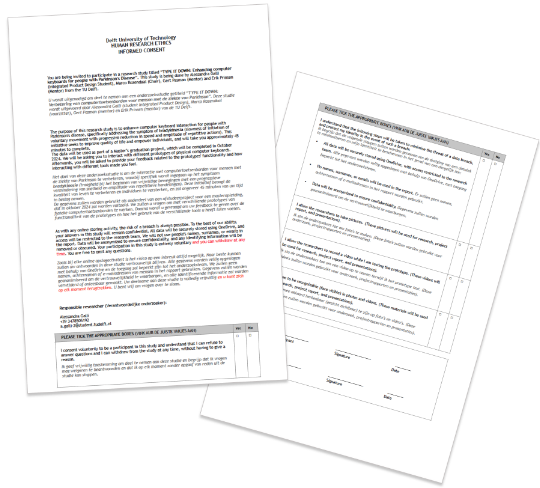
5 minuten **Inleiding**
/ Introduction

15 minuten **Prototypes uitproberen**
/ Try out prototypes

40 minuten **Presentatie en feedback**
/ Presentation and feedback

Alessandra Galli

September 2024



Toestemmingsformulier (Consent form)

Alessandra Galli

September 2024

Probeer alstublieft de prototypes uit :)
/ Please try out the prototypes.

Houd er rekening mee dat dit geen toetsenborden op ware grootte zijn vanwege praktische redenen.
/ Keep in mind that these are not full-sized keyboards for practicality purposes.

Toestemmingsformulier (Consent form)

Alessandra Galli

September 2024

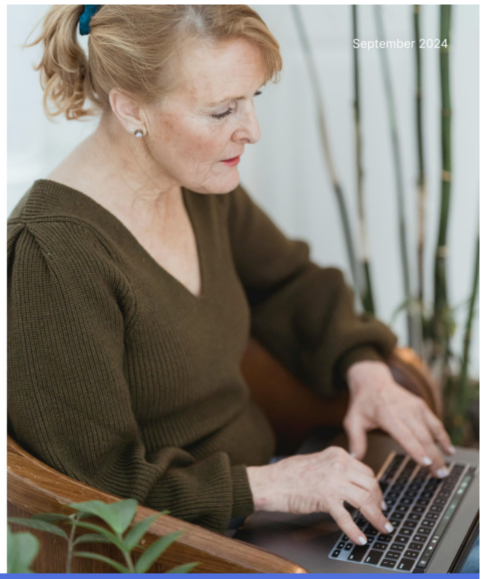
+**Tijd**
/ Time

+**Moe en gefrustreerd**
/ Tired and Frustrated

+**Fouten**
/ Mistakes

Het **computertoetsenbord kan worden gezien als een obstakel** voor gebruikers met de ziekte van **Parkinson**, waardoor hun vermogen om taken te voltooien wordt belemmerd.

*Dit leidt tot gevoelens van **frustratie**, vermijdingstendensen en verminderde betrokkenheid bij zowel professionele als persoonlijke activiteiten.*



Huidig probleem (Current problem)

Alessandra Galli

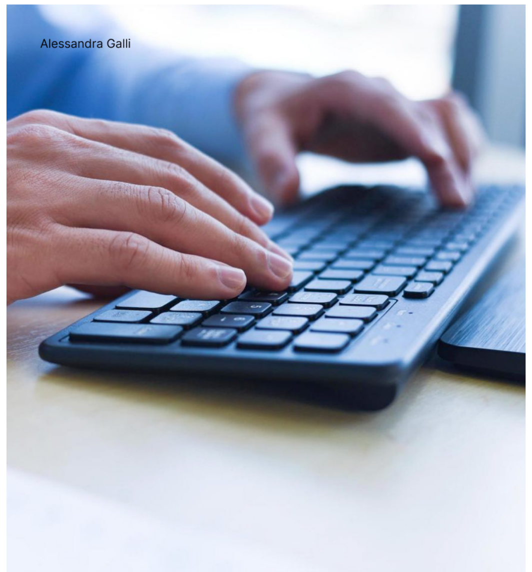
September 2024

Deze initiatief streeft ernaar om de kwaliteit van leven te verbeteren en **INDIVIDUEN TE VERSTERKEN**.

Dit project heeft als doel de interactie met computertoetsenborden te verbeteren voor mensen met de ziekte van Parkinson, met name door in te spelen op het symptoom **BRADYKINESIE**.

Doel van het project (Project's aim)

Alessandra Galli



26 June 2024

"Traagheid bij het initiëren van vrijwillige bewegingen met een geleidelijke vermindering van de snelheid en amplitude van herhalende handelingen."

In de motorische fysiologie bekend als het sequentie-effect.

Bradykinesie (Bradykinesia)

Alessandra Galli

26 June 2024

Cueing techniques

*"Cuing kan worden gedefinieerd als het gebruik van **externe stimuli** die temporele (met betrekking tot tijd) of ruimtelijke (met betrekking tot ruimte) informatie bieden om het initiëren en voortzetten van beweging te vergemakkelijken."*

example of product with cueing technique integration

HOE? (How?)

Alessandra Galli

26 June 2024

SOMATOSENSORISCH CUEING
/ SOMATOSENSORY CUEING

Somatosensorische cueing maakt gebruik van tactiele of proprioceptieve stimuli, zoals fysieke aanraking of balanstrainingen, om het initiëren en beheersen van beweging te verbeteren door het bevorderen van lichaamsbewustzijn en proprioceptie.

VISUELE CUEING
/ VISUAL CUEING

Visuele cueing gebruikt visuele stimuli, zoals lijnen op de vloer, om beweging te sturen en bevriezingsepisodes te verminderen.

AUDITIEVE CUEING
/ AUDITORY CUEING

Auditieve cueing maakt gebruik van ritmische auditieve signalen, zoals metronoomslagen of muziek, om bewegingen te synchroniseren en looppatronen te verbeteren bij mensen met motorische problemen.

Cue-technieken (Cueing techniques)

Alessandra Galli

September 2024

SOMATOSENSORISCH CUEING

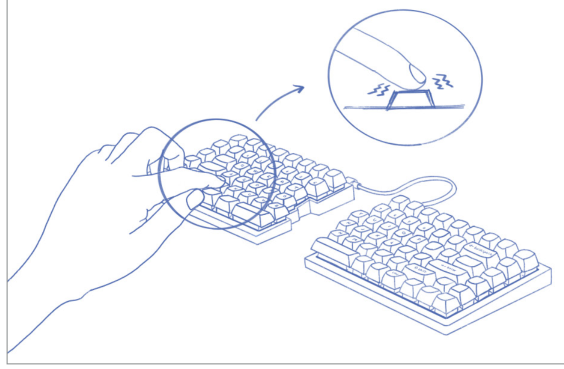
Somatosensorische cueing maakt gebruik van tactiele of proprioceptieve stimuli, zoals fysieke aanraking of balanstrainingen, om het initiëren en beheersen van beweging te verbeteren door het bevorderen van lichaamsbewustzijn en proprioceptie.

Somatosensorisch cueing (*Somatosensory cueing*)

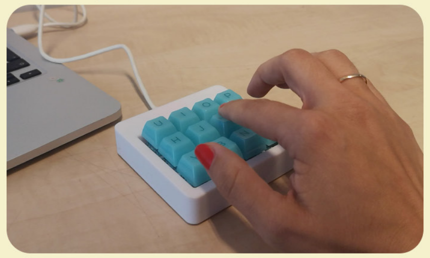
1

a. VIBRATING KEYS
Elke keer dat er een toets wordt ingedrukt, trilt de schakelaar.

b. STUCK FINGER
Als een vinger op een toets blijft hangen, wordt de trilling intenser om aan te sporen de vinger op te tillen, en wordt slechts één toetsaanslag geregistreerd bij voortdurende druk.



a. vibrating keys



b. stuck finger

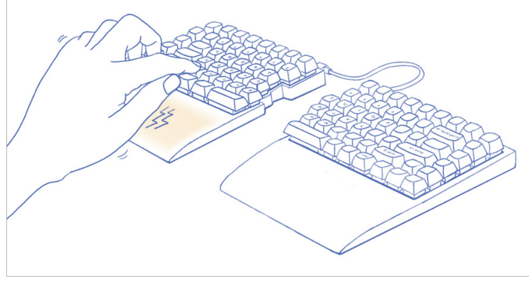
1. Denkt u dat deze functie uw interactie met het computertoetsenbord zou kunnen verbeteren? Waarom? / Do you think this feature could improve your interaction with the computer keyboard? Why?
2. Hoe voelt u zich daarbij? / How does it make you feel?
3. Ziet u nog andere mogelijkheden die verband houden met deze functie? / Do you see any other opportunities related to this feature?

2

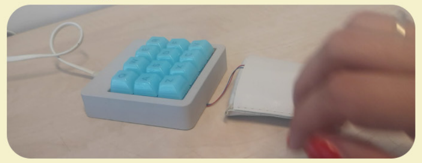
a. VIBRATING PALM REST
Elke keer dat er een toets wordt ingedrukt, trilt de handpalmsteun.

b. STUCK FINGER
Als een vinger op een toets blijft hangen, trilt de handpalmsteun herhaaldelijk om het optillen te stimuleren, en wordt er bij constante druk slechts één letter getypt.

c. FREEZING PREVENTION
Als er vijf seconden geen toetsen worden ingedrukt, trilt de handpalmsteun om aan te sporen te typen. In het uiteindelijke ontwerp kunnen gebruikers de vertraging naar wens aanpassen.

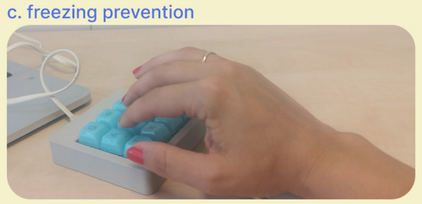


a. vibrating palm rest



b. stuck finger

c. freezing prevention



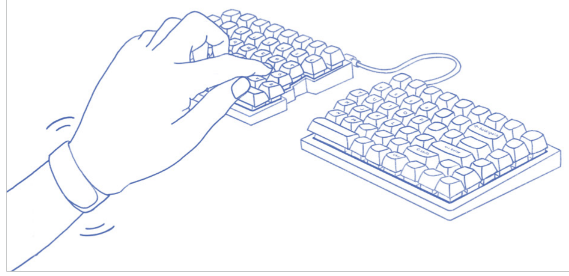
1. Denkt u dat deze functie uw interactie met het computertoetsenbord zou kunnen verbeteren? Waarom? / Do you think this feature could improve your interaction with the computer keyboard? Why?
2. Hoe voelt u zich daarbij? / How does it make you feel?
3. Ziet u nog andere mogelijkheden die verband houden met deze functie? / Do you see any other opportunities related to this feature?

3

a. VIBRATING CUFF
Elke keer dat een toets wordt ingedrukt, vibreert de manchet. In het uiteindelijke ontwerp kunnen gebruikers de intensiteit van de vibratie naar wens aanpassen.

b. STUCK FINGER
Als een vinger op een toets blijft hangen, vibreert de manchet om het optillen te stimuleren, en wordt er bij constante druk slechts één letter getypt.

c. FREEZING PREVENTION
Als er vijf seconden geen toetsen worden ingedrukt, vibreert de manchet om aan te sporen te typen. In het uiteindelijke ontwerp kunnen gebruikers de vertraging naar wens instellen.



a. vibrating cuff

b. stuck finger

c. freezing prevention

1. Denkt u dat deze functie uw interactie met het computertoetsenbord zou kunnen verbeteren? Waarom? / Do you think this feature could improve your interaction with the computer keyboard? Why?
2. Hoe voelt u zich daarbij? / How does it make you feel?
3. Ziet u nog andere mogelijkheden die verband houden met deze functie? / Do you see any other opportunities related to this feature?

AUDITIEVE
CUEING

Auditieve cueing maakt gebruik van ritmische auditieve signalen, zoals metronoomslagen of muziek, om bewegingen te synchroniseren en looppatronen te verbeteren bij mensen met motorische problemen.

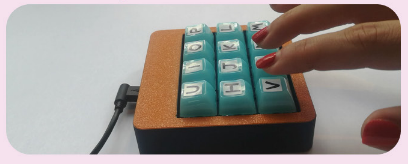
Auditieve cueing (*Auditory cueing)*

4

a. MELODIC KEYS
Elke toetsaanslag speelt een geluid af, wat directe feedback geeft en de typervaring verbetert.

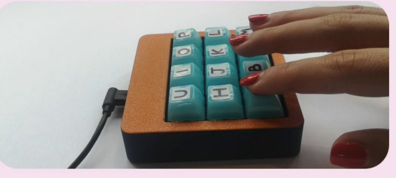
b. STUCK FINGER
Als een vinger op een toets blijft hangen, verhoogt het toetsenbord de geluidsintensiteit om het optillen te stimuleren, en wordt bij voortdurende druk slechts één toetsaanslag geregistreerd.

c. FREEZING PREVENTION
Als er vijf seconden geen toetsen worden ingedrukt, geeft het toetsenbord geluiden om aan te sporen te typen. Gebruikers kunnen de vertraging naar wens aanpassen.

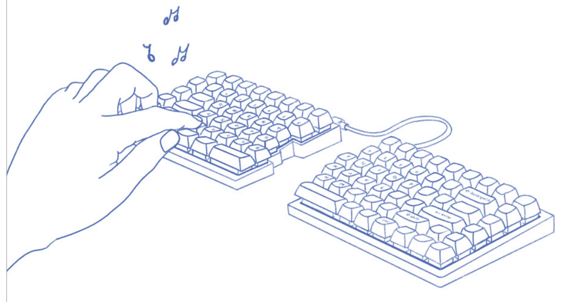


a. melodic keys

b. stuck finger



c. freezing prevention



1. Denkt u dat deze functie uw interactie met het computertoetsenbord zou kunnen verbeteren? Waarom? / Do you think this feature could improve your interaction with the computer keyboard? Why?

2. Hoe voelt u zich daarbij? / How does it make you feel?

3. Ziet u nog andere mogelijkheden die verband houden met deze functie? / Do you see any other opportunities related to this feature?

VISUELE
CUEING

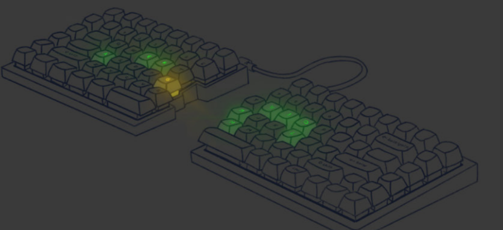
Visuele cueing gebruikt visuele stimuli, zoals lijnen op de vloer, om beweging te sturen en bevriezingsepisodes te verminderen.

Visuele cueing (*Visual cueing)*

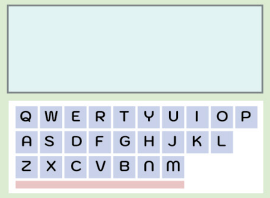
5

Feature NEXT POSSIBLE LETTERS

Wanneer een letter wordt ingedrukt, licht deze op in geel en worden alleen de mogelijke letters die op dat woord kunnen volgen in de geselecteerde taal groen verlicht. Dankzij kunstmatige intelligentie zullen, naarmate het woord wordt getypt, steeds minder letters oplichten, wat visuele feedback biedt.



1. Uitgeschakeld toetsenbord

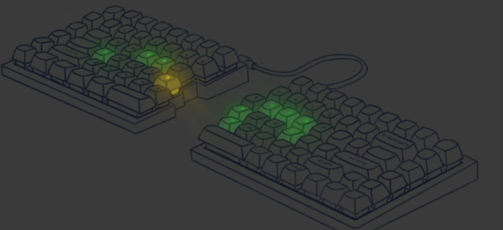


2. De gebruiker drukt op de letter C. De C licht op in geel. De mogelijke letters die op de C kunnen volgen, lichten op in groen.

5

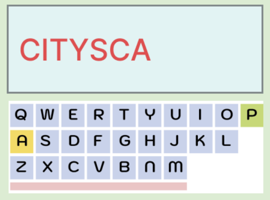
Feature NEXT POSSIBLE LETTERS

Wanneer een letter wordt ingedrukt, licht deze op in geel en worden alleen de mogelijke letters die op dat woord kunnen volgen in de geselecteerde taal groen verlicht. Dankzij kunstmatige intelligentie zullen, naarmate het woord wordt getypt, steeds minder letters oplichten, wat visuele feedback biedt.



3. De gebruiker drukt op de letter I. De C licht op in geel. De mogelijke letters die op CI kunnen volgen, lichten op in groen.

4. De gebruiker drukt op de letter A. De enige mogelijke letter na "citysca" is de letter P.

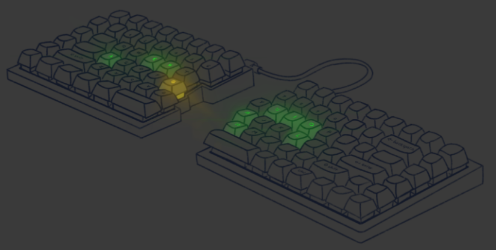


Alessandra Galli

5

Feature NEXT POSSIBLE LETTERS

Wanneer een letter wordt ingedrukt, licht deze op in geel en worden alleen de mogelijke letters die op dat woord kunnen volgen in de geselecteerde taal groen verlicht. Dankzij kunstmatige intelligentie zullen, naarmate het woord wordt getypt, steeds minder letters oplichten, wat visuele feedback biedt.



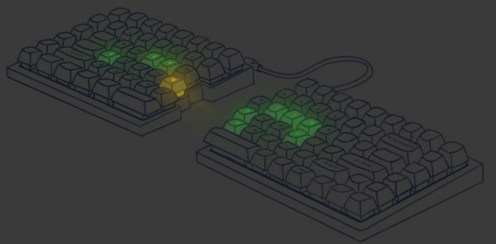
Zodra het woord is voltooid, wordt de spatiebalk ingedrukt om het toetsenbord uit te schakelen.

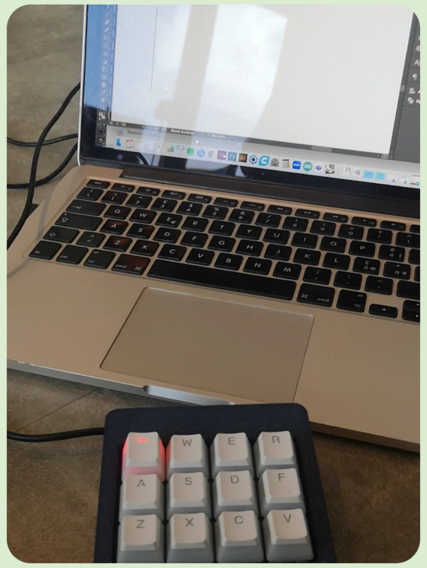
Alessandra Galli

5

Feature NEXT POSSIBLE LETTERS

Wanneer een letter wordt ingedrukt, licht deze op in geel en worden alleen de mogelijke letters die op dat woord kunnen volgen in de geselecteerde taal groen verlicht. Dankzij kunstmatige intelligentie zullen, naarmate het woord wordt getypt, steeds minder letters oplichten, wat visuele feedback biedt.





Alessandra Galli

September 2024

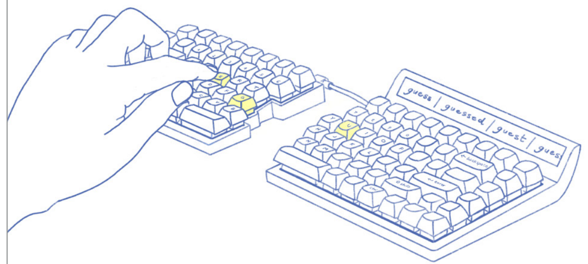
1. Denkt u dat deze functie uw interactie met het computertoetsenbord zou kunnen verbeteren? Waarom? / Do you think this feature could improve your interaction with the computer keyboard? Why?
2. Hoe voelt u zich daarbij? / How does it make you feel?
3. Ziet u nog andere mogelijkheden die verband houden met deze functie? / Do you see any other opportunities related to this feature?

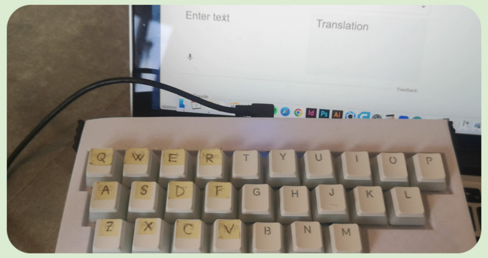
Alessandra Galli

6

WORDS SUGGESTIONS

Dit concept maakt gebruik van een bekende functie: woordsuggesties zoals op telefoons. Het toetsenbord heeft een LED-display dat suggesties toont wanneer toetsen worden ingedrukt. Bijvoorbeeld, na het typen van G, U, E verschijnen opties zoals "guess", "guessed" en "guest". De gebruiker kan dan een woord selecteren zonder verder te typen.





Alessandra Galli

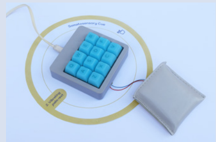
September 2024

1. Denkt u dat deze functie uw interactie met het computertoetsenbord zou kunnen verbeteren? Waarom? / Do you think this feature could improve your interaction with the computer keyboard? Why?
2. Hoe voelt u zich daarbij? / How does it make you feel?
3. Ziet u nog andere mogelijkheden die verband houden met deze functie? / Do you see any other opportunities related to this feature?

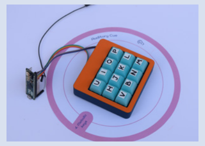
Appendix I

Results

CONCEPTS	FEEDBACK
Concept 1 	**Do you think this feature could improve your interaction with the computer keyboard? Why?** User 1: Yes, it basically takes over the function of the hand, when ending pressing a key is not "sensed"/defined. Hand is triggered to end pressuring. User 2: Yes, more interaction with the computer. More feedback. Better results. Fewer mistakes. User 3: You should use it for a longer period of time. User 4: No, it seems to slow things down instead. User 5: Too distracting. User 6: I think so, but it's difficult since I type two handed. User 7: It doesn't seem helpful to me; the noise disturbance seems more irritating. User 8: Yes, but it should be adjustable. **How does it make you feel?** User 1: Opens opportunities / Hope! User 2: A little strange. User 3: Restless User 4: unrelaxed / unpleasant User 6: Would be happy if it worked User 7: Not good, irritation User 8: I'm ok with it. **Do you see any other opportunities related to this feature?** User 2: The more feedback the better result. User 3: No User 6: I would like vibrations but noy the noise. I don't want my colleagues to ge annoyed. User 7: A function to adjust the volume of the feedback. **Additional comments** User 1: The increase buzz when entering a key seems obsolete. User 5: I don't have issues with slowness, but with tremor. **Notes:** • "I can imagine concept 1 could help". • **Design Suggestions:** One person suggested, "Maybe you can have two designs, one for tremors and another for slowness." However, another person pointed out, "Sometimes I am slow, sometimes I have tremors." • **Concerns** - My colleagues might be annoyed by the sound of the vibration motor. • **Adjustability** - It would be helpful if the sound (vibration motor) is adjustable.

CONCEPTS	FEEDBACK
Concept 2 	**Do you think this feature could improve your interaction with the computer keyboard? Why?** User 1: No, irritates me. User 2: Yes, but I feel there is too much interaction. Too many senses are touched. User 3: No, not for me. Every vibration makes me restless. User 5: I preferer than 1. Less distracting. User 6: Too much vibration and sound. User 7: With a wristband/smartwatch, it might be more comfortable. User 8: No, I cannot think in what way this will be helpful. **How does it make you feel?** User 2: Getting more stressed. User 4: Way better than the first one. User 6: This will stress me out. User 7: Better than keyboard feedback (concept 1). **Do you see any other opportunities related to this feature?** User 2: Maybe a massage of the neck / shoulders. User 6: Nope **Additional comments** / **Notes:** • "More comfortable than concept 1". • "I prefer the palm rest compared to concept 1 and 3".

CONCEPTS	FEEDBACK
Concept 3 	**Do you think this feature could improve your interaction with the computer keyboard? Why?** User 1: Better than number 2, but seems distracting when working at the desk due to "hand cuffs" User 2: Yes. User 3: It seems to keep the hand calm. User 7: This is nice, but the feedback remains irritating. User 8: Better could be helpful on the wrist. **How does it make you feel?** User 2: Relaxed. User 3: Calm. User 6: It feels comfortable but not sure whether it works. **Do you see any other opportunities related to this feature?** User 2: Yes, more feedback. User 3: No **Additional comments** User 3: You should try it for a longer period of time. **Notes:** • "It just feels quite nice". • "The best of all of the 3".

CONCEPTS	FEEDBACK
Concept 4 	**Do you think this feature could improve your interaction with the computer keyboard? Why?** User 1: Sound is annoying. User 2: No, too many sensors. User 3: I don't like monotonous sounds. User 4: No, really annoying :) User 7: Irritating sound. **How does it make you feel?** User 2: Not relaxed, too much noise. User 6: Really annoying and distracting. **Do you see any other opportunities related to this feature?** / **Additional comments** / **Notes:** • One person mentioned, "I use music to help me relax," while another responded, "I never thought about music." • "I don't like noises".

CONCEPTS	FEEDBACK

Concept 5

Do you think this feature could improve your interaction with the computer keyboard? Why?

User 1: Might work for people who do not type "blind" but seems quite complicated / confusing.
User 2: No, makes me think about my phone type feature which I do not like.
User 3: In the long run, it could help with long distances.
User 4: I'm typing blind, but for people who don't it could be helpful.
User 5: Doesn't help with touch typing.
User 6: No because I type blind, I don't look at my keyboard.
User 7: No need for it.
User 8: For me a combination of this with sotware for speech detection could be helful.

How does it make you feel?

User 2: Too much stress.

Do you see any other opportunities related to this feature?

User 6: I do like the idea of AI learning from my typing behaviour / vocabulary / language and enable compliting words with spacebar.

Additional comments
/

Notes:
• "I don't look the keyboard while I type".

CONCEPTS	FEEDBACK

Concept 6

Do you think this feature could improve your interaction with the computer keyboard? Why?

User 1: Function already exists (in different form) in most social media / microsoft programmes.
User 2: I do not have problem with the flow.
User 3: Sounds interesting, but it doesn't help to type faster.

How does it make you feel?

User 2: Not relaxed.
User 6: I don't like the separate monitor, too complex, too much time.

Do you see any other opportunities related to this feature?
/

Additional comments
/

Notes:
• "But it is not for the flow".

Additional comments:

User 1: I am very positive / pleasantly surprised by option 1. Others will not work for me. Of course, given the nature of our disease, this is a very individual / semi objective opinion. Please keep in mind some people prefer a low / thin keyboard. I realized this is very difficult to achieve. Thank you for your efforts to help improve our quality of life. Grazie mille. Jan

User 2: Good research. I do not feel the need for more feedback for my computer. For people with MS (like me). I think we need less interactions with colours, sounds, light or vibration.

User 3: If the prototype can also be put into use, you will be able to see more results.

User 4: I really dislike sound: distracts me and others too. Vibration could be helpful. My preference: straps around the wrist. Light: not

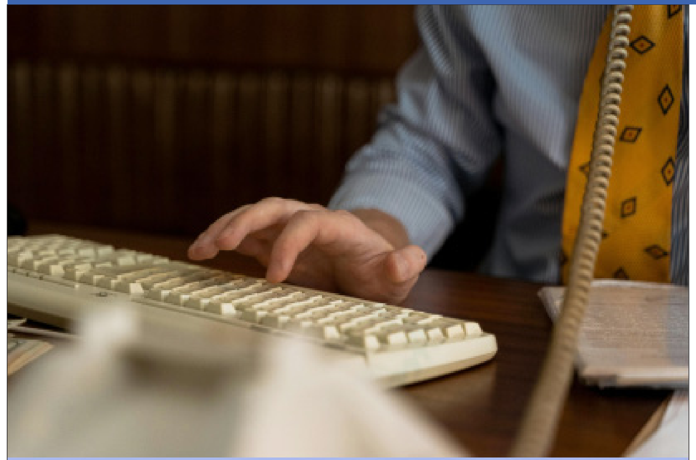
User 6: In general for me the most important is the height of the keys, the effort it takes to press them. The size of the keys. In your prototype you focused on "borders" but the keys are still flat, but I think height is important to have a certain border nect to every key. NB: the keys soundn't be as hight as the "small" prototypes. Etra: I don't suffer from freezing but from tremor.

User 8: I beg very large keyboard (check with someone)

Appendix J

Online forum, Key findings

Online Forum - Suggestions from people with PD



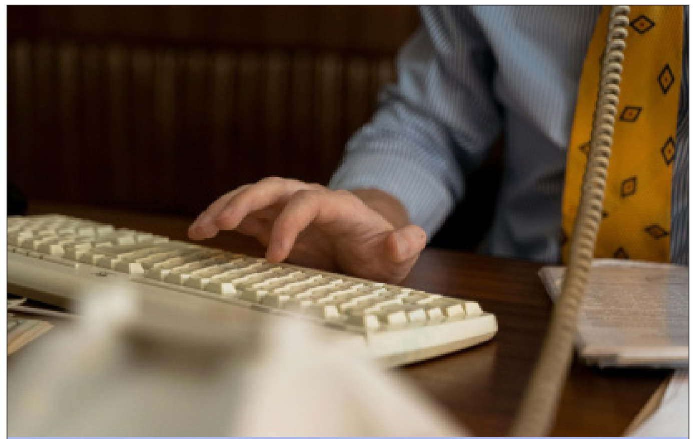
If you have a decent microphone you could use speech dictation, I use dragon by nuance. Google speech to text has become very good, so you could use that, its what i use on my smart phone

When I'm "off" I type with one finger, which is a problem if you want to type a capital letter.

https://forum.parkinsons.org.uk/t/use-of-computer-keyboard/11123/3
https://www.neurotalk.org/parkinson-s-disease/180800-typing-tips-pwp.html?highlight=typing

Some people may find using a keyboard easier than writing by hand. However, for others the straight-line set-up of the keyboard may be difficult, as it requires good control of your movements. Keys can also be quite sensitive – **you may find you repeatedly type a character because you're holding the key down for a long time. For some tasks, you may have to press two or more keys at the same time.** Your keyboard can be altered to help meet your needs. Accessibility features such as Filter Keys or Slow Keys tune your keyboard, so the length of time a key needs to be held down for before it appears or repeats on screen can be changed. **Sticky Keys allow you to operate a combination of keys using just one finger. You may find a keyguard useful.** This is a rigid plate with holes that are positioned over each key on your keyboard. The guard makes it impossible to press two keys at once. You can also rest your hands and arms on the guard without pressing any keys. There are other styles of keyboards available. Small and compact keyboards may be more suitable for singlehanded users. You can also buy specially designed ergonomically curved or two-part keyboards. **There are also keyboards with larger keys.** These can all be useful if you find it difficult to accurately find or press keys on a standard keyboard.

"**Sticky Keys**" is an accessibility feature that allows users to press modifier keys (Shift, Ctrl, Alt) one at a time instead of simultaneously, helping those with motor difficulties by reducing the need for complex finger movements. For example, instead of pressing Ctrl + Alt + Delete simultaneously, you can press Ctrl, then Alt, and then Delete in sequence.



My Parkinson's symptoms include (surprise, surprise!) severe difficulty in using a PC.

Specifically, my keyboard skills have deteriorated significantly over time - **I used to be a fast touch-typist but now I'm more of a one-fingered typist** - the biggest issue being my clobbering the wrong key alongside the key I intended to hit, and creating typo's which required correcting.

https://forum.parkinsons.org.uk/t/using-a-computer/5246

I also have problems with keys being wrongly repeated. For instance, I want to type the word forum but I get fooorum. Or when going back to correct the mistake I overrun, deleting good text as well as bad. To reduce this problem, **you can slow the speed at which the cursor moves.**
As my PD progresses it becomes worth learning more and more keyboard **short-cuts**.

I've found using a **wireless** keyboard is much easier than using the MacBook keyboard because you can put it anywhere.

https://www.reddit.com/r/Parkinsons/comments/1alia2b/any_advicehacks_for_using_a_computer_keyboard/

I think any mechanical **switch with a tactile bump** before or at actuation will help.

https://geekhack.org/index.php?topic=99596.0

Appendix K

Features explanation for OnCue software

Both the keyboard and cuffs feature a controller with easily accessible key settings, enabling users to adjust the main features with ease. Additionally, during installation, users can customize additional parameters, allowing the product to be tailored to their specific and diverse needs.

HAPTIC SWITCH

1. Regular Typing (Short Press)
Each time a key is pressed, the switch vibrates to provide feedback.
• Vibration Intensity: Adjust the strength of the switch's vibration. This control is also available on the keyboard itself.
• Vibration Duration: Modify the vibration duration for each action (short press), ranging from 0 to 4 seconds.

2. Stuck Finger (Long Press)
If a finger remains on a key for too long, the switch will gradually increase its vibration to encourage the user to lift their finger.
• Vibration Intensity: Adjust the strength of the switch's vibration.
• Vibration Duration: Modify the vibration duration for each action (long press), ranging from 1 to 8 seconds.

VISUAL CUE SWITCH

1. Light Intensity: This control is also available on the keyboard and adjusts the light intensity, as well as toggles the feature on and off.

2. Key Lighting on Press
Keys light up in yellow when pressed, providing immediate visual feedback to the user.
• On/Off: The user can enable or disable this function.

3. Suggested Next Letters
Based on the selected language, the most likely letters to follow the pressed key light up in green, helping guide the user toward the next character.
• On/Off: The user can enable or disable this function.
• Language Selection (Dutch/English): The user can select the language. This control is also available on the keyboard.

HAPTIC CUFF

1. Regular Typing (Short Press)
Each time a key is pressed, the cuff vibrates to provide feedback.
• Vibration Intensity: Adjust the strength of the cuff's vibration. This control is also available on the cuff itself using the + and - buttons.
• Vibration Duration: Modify the duration of the vibration for each action (short press), ranging from 0 to 4 seconds.

2. Stuck Finger (Long Press)
If a finger remains on a key for too long, the cuff will gradually increase its vibration to encourage the user to lift their finger.
• Vibration Intensity: Adjust the strength of the cuff's vibration.
• Vibration Duration: Modify the duration of the vibration for each action (long press), ranging from 1 to 8 seconds.

3. Freezing Prevention (Inactivity)
If no keys are pressed for a few seconds, the cuff vibrates to prompt the user to resume typing.
• Vibration Intensity: The strength of the cuff's vibration can be adjusted.
• Prompt Signal: The time after which the cuff vibrates can be set, with a maximum delay of 60 seconds. This control is also available on the cuff.
• Vibration Frequency & Number of Vibrations: These options allow the user to customize the vibration pattern. The first setting defines the frequency (how often the vibration occurs), and the second setting specifies the number of vibrations the user would like to receive.
These settings are available for both the left and right cuffs.

Appendix L

Haptic feedback uses touch to communicate with users. Common haptic technologies include:

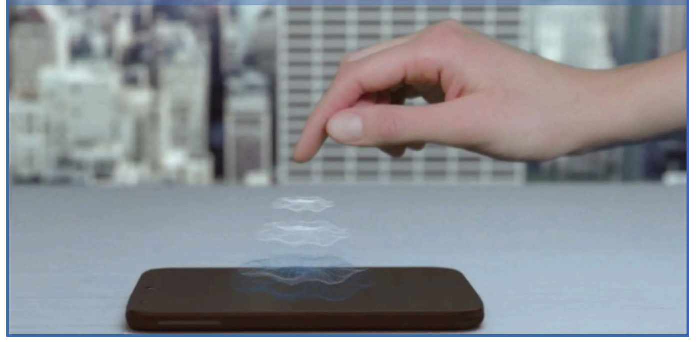
Vibrotactile haptics

Small motors in devices like phones and game controllers produce vibrations.

China Customized ERM Vibration Motor Suppliers & Manufacturers & Factory - Made in China - Ineed Electronics. (n.d.). https://www.ineedmotors.com/vibration-motor/erm-vibration-motor.html

Ultrasonic mid-air haptics

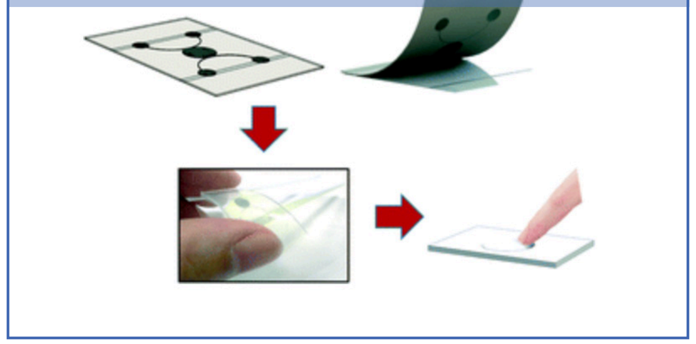
Ultrasound waves create a “virtual touch” sensation without physical contact.



Haptic feedback: the next step in smart interfacing | imec. (n.d.). Imec. https://www.imec-int.com/en/imec-magazine/imec-magazine-june-2020/haptic-feedback-the-next-step-in-smart-interfacing

Microfluidics

Air or liquid in smart textiles creates pressure or temperature on the skin.



Yeo, J. C., Yu, J., Koh, Z. M., Wang, Z., & Lim, C. T. (2016). Wearable tactile sensor based on flexible microfluidics. Lab on a Chip, 16(17), 3244–3250. https://doi.org/10.1039/c6lc00579a

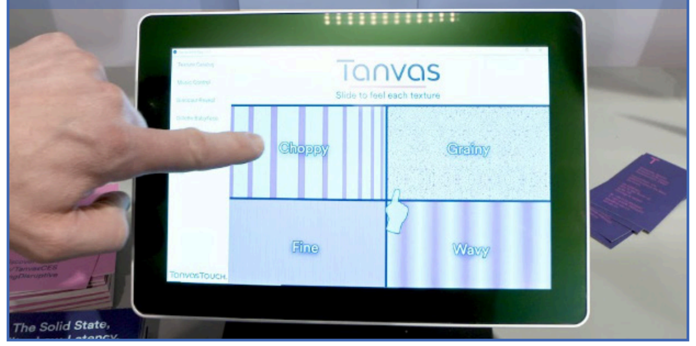
Force control

Mechanical devices apply force to the user’s body.

Force Dimension - Haptic devices. (n.d.). Force Dimension. https://www.forcedimension.com/products

Surface haptics

Alters friction on touchscreens for tactile effects.



Microchip Technology, Inc. (2020, March 30). Smart surface & localized haptics [Video]. YouTube. https://www.youtube.com/watch?v=X-EPIGRa0_U

Appendix M

Prompt example Chat GPT.

Half KEYBOARD with haptic feedback integrated in three switches:

BASIC FEATURE
prompt

I built a hand-wired keyboard matrix with 5 columns and 3 rows. I am using an (Arduino) Pro Micro board.
The keys in the first row have the following letters in order: t, r, e, w, q. The second row has the letters g, f, d, s, a. The third row has the letters b, v, c, x, z.
Each key (switch) has two pins. All the negative pins of the switches are connected vertically to form the columns. All the positive pins of the switches are connected horizontally to form the rows. Row 1 is connected to pin 2 of the Pro Micro board, row 2 is connected to pin 3, and row 3 is connected to pin 4. The columns are connected as follows: column 1 to pin 10, column 2 to pin 16, column 3 to pin 14, column 4 to pin 15, and column 5 to pin A0. Write the code and use the Keyboard.h library.

I updload the code on Arduino and test the prototype.
Does the code work?

YES ↓

NO → I tell ChatGPT that it did not work, and I ask what could be the different causes to analyze them.

ADDITONAL FEATURE (adding complexity)
prompt

I added three vibration motors, one for the ‘F’ key, one for the ‘C’ key, and one for the ‘S’ key. The motor associated with the ‘F’ key is connected to pin 8, the one for the ‘C’ key is connected to pin 7, and the one for the ‘S’ key is connected to pin 6. When one of these keys is pressed, the corresponding motor should vibrate. If the key remains pressed for more than 1 second, the vibration should intensify.

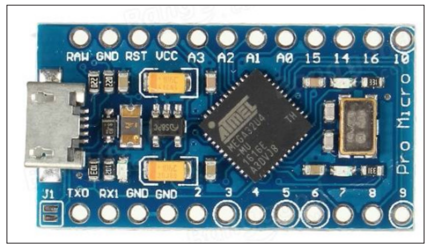
I updload the code on Arduino and test the prototype.
Does the code work?

YES

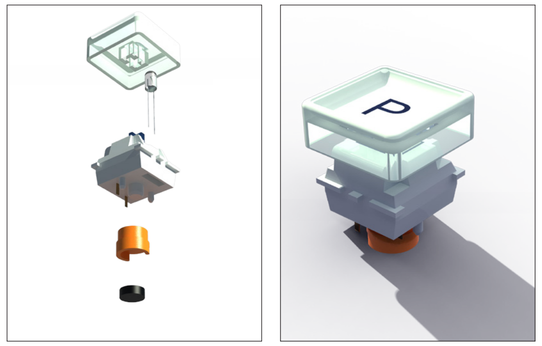
NO → I tell ChatGPT that it did not work, and I ask what could be the different causes to analyze them. I ask if there are different approaches to achieve what I want.

Keyboard layout

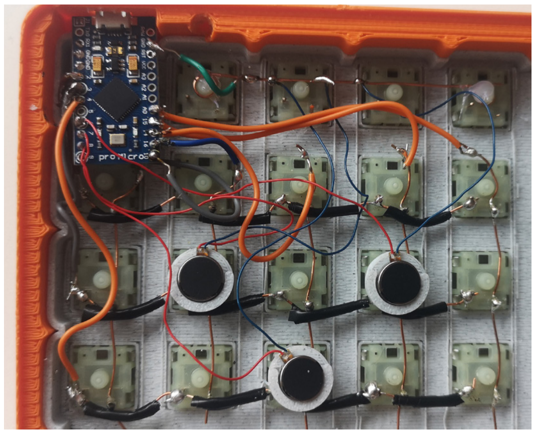
Switches with integrrated motor vibrator



Pro Micro board



Module switch + vibrator motor



Prototype

Components

Appendix N

Project Brief

DESIGN FOR our future

TUDelft

IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME
Complete all fields and indicate which master(s) you are in

Family name	Galli	IDE master(s)	IPD ✔ Dfl ☐ SPD ☐
Initials	A.	2nd non-IDE master	
Given name	Alessandra	Individual programme *(date of approval)*	
Student number	5617154	Medisign	☐
		HPM	☐

SUPERVISORY TEAM
Fill in he required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair	Marco Rozendaal	dept./section	HICD
mentor	Gert Pasman	dept./section	DCC
2nd mentor	Erik Prinsen		
client:	ParkinsonNL		
city:	Delft	country:	Netherlands
optional comments			

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.

! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.

! 2nd mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in by the Chair of the supervisory team

Sign for approval (Chair)

Name Marco Rozendaal Date 16-05-2024 Signature

CHECK ON STUDY PROGRESS
To be filled in by SSC E&SA (Shared Service Centre, Education & Student Affairs), after approval of the project brief by the chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total	EC
Of which, taking conditional requirements into account, can be part of the exam programme	EC

★	YES	all 1st year master courses passed
	NO	missing 1st year courses

Comments:

Sign for approval (SSC E&SA)

Name Date Signature

APPROVAL OF BOARD OF EXAMINERS IDE on SUPERVISORY TEAM -> to be checked and filled in by IDE's Board of Examiners

Does the composition of the Supervisory Team comply with regulations?

YES		Supervisory Team approved
NO		Supervisory Team not approved

Comments:

Based on study progress, students is ...

	ALLOWED to start the graduation project
	NOT allowed to start the graduation project

Comments:

Sign for approval (BoEx)

Name Date Signature

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

The problem addressed is that the computer keyboard can be perceived as a barrier for users with Parkinson's Disease, hindering their ability to complete tasks on the computer due to the disease affecting their nervous system and nerve-controlled body parts. This leads to feelings of frustration, avoidance tendencies, and reduced engagement in both professional and personal activities.

There is an opportunity to explore the integration of cueing techniques to enhance the user experience while using a physical keyboard, thereby improving their quality of life.
Although cueing techniques have been used in assistive devices, their application in supporting upper extremity functions, especially arms, hands, and fingers, has been relatively limited. Preliminary studies suggest that auditory cues may enhance movement variability among individuals with PD who exhibit reduced finger tapping variability. Additionally, investigating haptic feedback through vibrations shows promise, inspired by research indicating its effectiveness in alleviating freezing episodes, improving postural alignment, and enhancing vocal projection.This graduation project aims to seamlessly integrate these cueing techniques to improve typing efficiency while prioritizing user preference and comfort.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Develop a concept by delivering a physical prototype to assess the integration of cueing techniques in a computer keyboard to support individuals with Parkinson's disease, focusing on the bradykinesia symptom in their interaction with it, in the context of design for health and social well-being.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

My project approach follows the principles of User-Centered Design (UCD), emphasizing the user perspective to develop valuable and usable products, while also integrating the Double Diamond Method as a guiding framework. This method comprises four key stages: Discover, Define, Develop, and Deliver. The overall concept is to diverge during the exploration phases and converge during the refinement phases.

The Discover phase entails extensive user research, focus group, literature reviews on Parkinson's Disease, needs analysis, examination of existing technologies, and cueing techniques research. Transitioning to the Define phase, I will synthesize insights to establish clear goals and requirements, crucial for improving comprehension and guiding later stages. In the Develop phase, both conceptualization and prototyping occur, progressing from low to high fidelity, informed by rigorous testing and user feedback. Lastly, the Deliver phase centers on user evaluation, refining the final concept and prototype based on feedback and offering recommendations for future enhancements.

introduction (continued): space for images

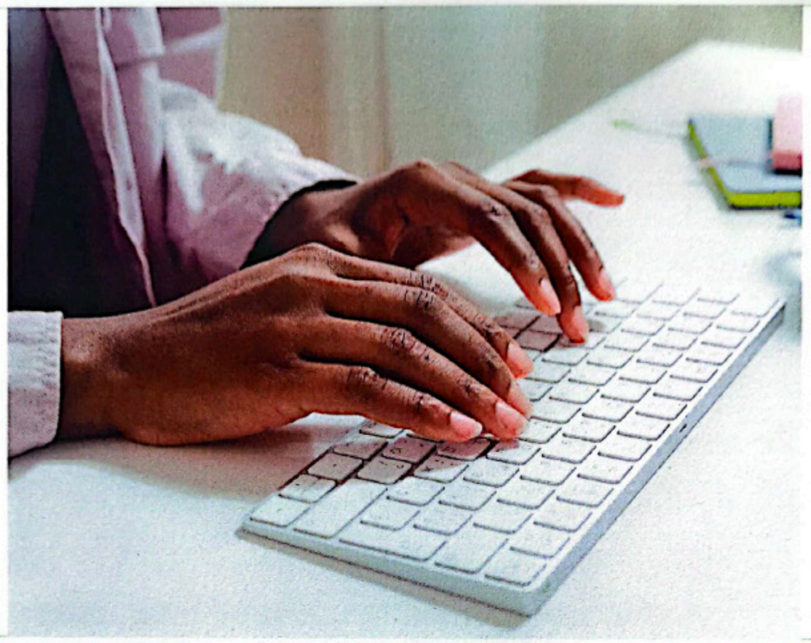


image / figure 1 Computer Keyboard

image / figure 2 Parkinson's Disease, movement impairment symptom

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Name student Alessandra Galli **Student number** 5,617,154

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title TYPE IT DOWN: Enhacing computer keyobards for people with Parkinson's Disease.

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

The project's domain is design for health and social well-being, focusing on Parkinson's Disease (PD) and its impact on individuals' daily lives, particularly on interaction with a common tool: the computer keyboard.
With approximately 53,000 diagnosed PD patients in the Netherlands, PD is a progressive disorder that affects the nervous system and parts of the body controlled by the nerves, causing issues with movement, mental health, sleep, pain, and other health concerns. Though incurable, therapies and medicines exist to alleviate symptoms. Bradykinesia, a hallmark PD symptom, is characterized by slowed movements that hinder fine motor skills, complicating tasks such as keyboard use.

Primary stakeholders include PD-affected individuals. Other stakeholders are Assistive Innovations, Roessingh Research and Development, and Radboud University Medical Centre, entities joining forces to address this issue, securing funding from ParkinsonNL to explore integrating "cueing techniques." These techniques entail using external cues, such as auditory prompts and haptic feedback, to aid in initiating and executing movements.
People with Parkinson's disease face challenges in executing sequential movements and experience delayed reaction times when using keyboards, leading to frustration and avoidance behaviors. However, there are significant opportunities by embracing a user-centered approach that actively involves the target group. It is possible to enhance their quality of life, foster social engagement, and empower individuals. Moreover, such an approach allows for tailored solutions to address the unique needs and preferences of each person with PD.
Despite these promising opportunities, it is essential to acknowledge the inherent limitations arising from the complexity and variability of PD symptoms, as well as individual differences in how PD manifests and affects interactions with keyboards.

→ *space available for images / figures on next page*

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting, mid-term evaluation meeting, green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	16 May 2024
Mid-term evaluation	9 Jul 2024
Green light meeting	17 Sep 2024
Graduation ceremony	15 Oct 2024

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

I am genuinely passionate about dedicating the next five months to a project aimed at significantly improving people's lives and allowing me to engage directly with individuals from the target group. Reflecting on the use of a keyboard, I've realized that for me, it is simply a tool for work or other activities, barely capturing my attention. However, recognizing that for others, it can be perceived as a barrier deepens my commitment to addressing this challenge. I firmly believe that design, as a discipline, can simplify complex problems and should serve as a tool to enhance people's lives, especially considering the worldwide prevalence of Parkinson's disease and the absence of a cure.

My primary goal is to develop a product that successfully meets users' needs by incorporating their feedback and I aim to effectively manage all stakeholders involved. Moreover, with this project, I aim to demonstrate that I can independently carry out all phases, without relying on a group effort. I intend to integrate knowledge from both my work experience and academic background, seamlessly combining functionality and aesthetics.