# The Runner Mouse

**Amit Rovshitz**
*Ariel University*

**Avihay Finish**
*Ariel University*

**Elad Laster**
*Ariel University*

October 26, 2024

**Project Advisor: Dr. Arel David Segal-Halevi**
*Ariel University*

# Contents

# 1 Problem Statement And Background

## 1.1 Introduction of the Problem

Our project aims to support patients in rehabilitation, specifically those recovering from strokes or injuries that have severely impacted hand mobility. In collaboration with Beit Loewenstein, we envisioned creating a computer game to train and assess hand mobility, offering patients a gradual path to recovery.

For many, even simple tasks like opening and closing their hands become extremely challenging after injury. Regular hand exercises are essential for regaining control and strength, but the difficulty and repetitiveness of these exercises often make it hard for patients to stay motivated.

Currently, Beit Loewenstein utilizes a rehabilitation game intended to assist doctors with hand mobility exercises. However, this game lacks engagement, and some patients even fall asleep while using it. We believe that a more interactive, visually appealing, and enjoyable game could make a substantial difference. By enhancing the rehabilitation process and sustaining patient motivation, such a game could ultimately contribute to improved recovery outcomes.

## 1.2 Current Rehabilitation Methods

Today, Beit Loewenstein uses a basic therapeutic game designed to help patients practice hand movements. This game integrates with the Amadeo device, which attaches to the patient's fingers, allowing every finger movement to be displayed on the screen. The goal is to guide the patient through various exercises on the device, progressively improving finger movement and strength. The game provides instructions on which finger to move, as illustrated below:

At the top of the display, there is a visual representation of both hands with all 10 fingers, where each box at the bottom corresponds to a specific finger. The game continuously tracks the force applied by each finger and displays this data in real-time using white horizontal lines that reflect the patient's movements.

Blue arrows indicate the direction each finger should move—an upward arrow means the patient should raise their finger, while a downward arrow signals that they should bend it. During exercises, only one hand connects to the machine, and the horizontal lines on the screen represent each finger's position. The patient must move their fingers up or down, keeping the horizontal line within a green target area.

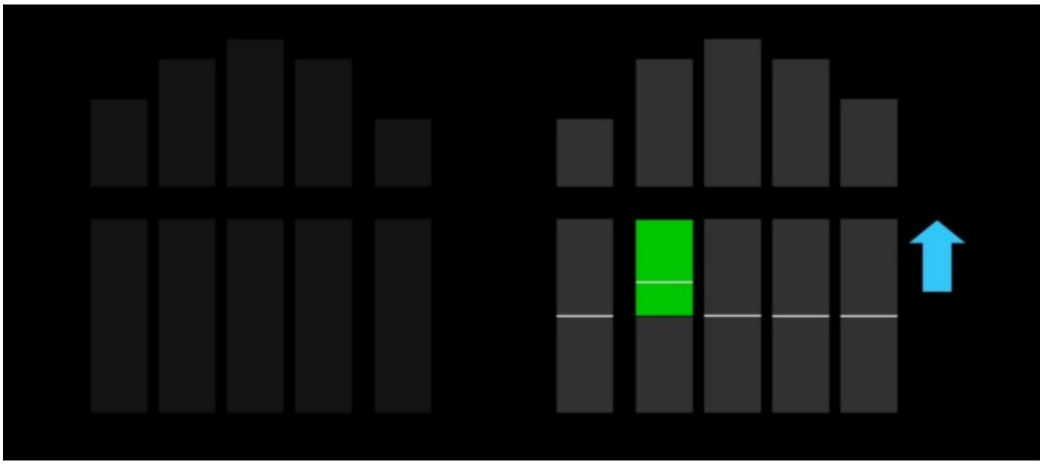

Figure 1: Illustrate one

Figure 2: Illustrate two

Upon connecting to the Amadeo device, a calibration process called ZeroF is performed. The patient relaxes their fingers while connected to the machine, allowing for an analysis of resting forces on the device. When force is applied, these resting forces are subtracted, ensuring that only the patient's exerted forces are measured accurately.

# 2 Project Objectives

The current game is developed for the "Beit Loewenstein" rehabilitation center. At this center, the Amadeo machine is used to detect the forces applied by the patient's fingers. This machine helps patients restore movement abilities, stability, strength, and more. To encourage patients to engage with the machine and complete their tasks, we developed this game, which interfaces with the Amadeo machine.

### 2.1 Adjusting the Difficulty for Each Patient

One of the most interesting features of our game is that the therapist can adjust the difficulty to suit each patient's needs. The therapist creates a CSV file (which we will discuss in more detail later in the article), uploads it to the game, and the game generates a world based on the instructions from the file. This gives the therapist the flexibility to design an easy game for beginner patients, requiring only simple movements and minimal force from the Amadeo, or to create a more challenging game for advanced patients.

### 2.2 The Game Objective

In this game, the player controls a mouse moving through a tunnel. The mouse has a constant horizontal speed (on the x-axis), and its vertical movement is controlled by the player's finger on the Amadeo device (the therapist can select which finger the patient will use). The goal for the patient is to keep the mouse as close to the center of the tunnel as possible. The closer the mouse is to the center, the higher the score (we will discuss how the score is calculated later in the article). The length of each tunnel segment, its width, and the sharpness of the turns are determined by the therapist through the settings in the file.

### 2.3 Objective Conclusion

The main goal for the patient (the player) is to reach the end of the tunnel. The closer they keep the mouse to the center of the tunnel during this journey, the higher their score will be. The player has five chances to collide with the tunnel walls before losing the game.

## 3 Methodology

Before each game, the therapist selects which finger the patient will use to control the vertical movement of the mouse. This approach allows us to focus on improving a specific finger's strength, stability, and coordination over time. By tracking progress, we can assess any improvements in finger movement and strength. Additionally, we aim to evaluate whether the use of the Amadeo machine and the interactive game encourages the patient to engage more effectively in their rehabilitation tasks.

## 3.1 Checking Improvements

As mentioned earlier, the player's score in the game is determined by how close they are to the center of the tunnel. This provides an additional method for assessing improvements in the patient's finger strength, stability, and coordination. When testing the game with the Amadeo machine, we observed the challenge of this task due to the machine's sensitivity to finger movements. To keep the mouse centered in the tunnel, the player must remain stable and apply consistent force to prevent the button on the machine from moving. In addition to the standard metrics used by the therapist to assess finger improvement, they can now also evaluate the player's game score as an indicator of progress—higher scores may reflect better control and stability.

### 3.1.1 Score Calculation

The score increases based on how close the mouse is to the center of the tunnel. Conceptually, the tunnel is defined by a line generated from the CSV file. Along this line, we add the top and bottom walls of the tunnel according to the width column from the file (we will discuss this in detail later). In each segment of the tunnel, we have a center line, and thus, we can determine the `y` value of the center for any given `x` coordinate along the tunnel. In each frame of the game (within Unity's `Update` function), we calculate the distance between the mouse's `y` position (corresponding to the current `x` value of the mouse) and the tunnel's center `y` position. The player is awarded points only if this distance is less than 0.2. If the distance is exactly zero (the `y` coordinates are the same at that `x`), the score increases by 10 points. Otherwise, the score increases by the absolute value of the logarithm in base 10 of the distance:

$$\text{score increment} = |\log_{10}(\text{distance})|$$

Additionally, if the score is calculated using the logarithm, the distance is constrained to a minimum value of $10^{-4}$, because the logarithm of smaller values can approach negative infinity, and computer systems may struggle with extremely big numbers.

# 4 Critical Components of the Game Design

The game consists of three main parts. The first part is the main menu scene. This is the scene that the player sees when they start the game. It consists only of a menu where they can navigate to the game settings and the game itself (the player must go to the settings first for the game to work properly).

## 4.1 The Settings Scene

In this scene, the player needs to adjust some settings. First, they need to determine the speed of the mouse (this setting affects the entire game). Second, the player chooses the CSV file that the game uses to build the world. Third, there is a "zeroF" button. The player needs to press this button if they are playing the game with the Amadeo machine (there is an option to play with the keyboard for development purposes). This button calibrates settings related to the machine. Finally, the therapist choose the finger that the patient will use in the game.

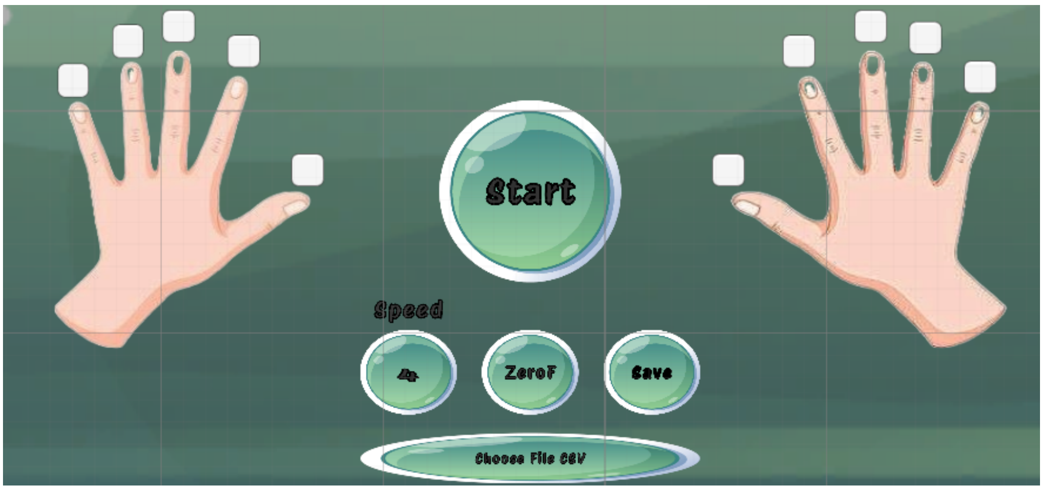


Figure 3: The setting scene

### 4.1.1 The CSV File

The CSV file needs to have three columns: **Time**, **Target**, and **Width**.

1. The **Time** column represents the seconds it will take for the mouse to pass through the current segment of the tunnel. The length of the segment

is calculated by multiplying the speed defined by the player in the settings scene by the value in the Time column for the current line.

2. The **Target** column generally represents the angle of the segment, indicating where the segment will move along the y-axis as a percentage of half the screen height. If the target is zero, the segment will move towards the center of the screen. A negative target value shifts the segment below the center, while a positive target shifts it above. The Target value should be between -100 and 100.

3. The **Width** column defines the width of the current segment as a percentage of the entire screen. After adjusting the target position as a percentage of half the screen, the top wall is placed above the target by half of the gap, and the bottom wall is placed below the target by half of the gap. The Width value should be between 20 and 100, with the lower limit accounting for the mouse width.

For example, the line `6,50,30` creates a segment where the mouse will pass in six seconds. The center of the segment will be positioned at 50% of the top half of the screen, and the width of the segment will be 30% of the screen.

### 4.1.2 Problems With the Values in the File

The values defined in the file can create issues during world building, and we need to address them.

Beyond the obvious problems, such as when the ‘target‘ is greater than 100 or smaller than -100, or when the ‘width‘ is greater than 100 or smaller than 20 (which are easy to handle), there can be more complex issues related to the connection between the ‘target‘ and the ‘width‘. For example, if the ‘target‘ is 80 and the ‘width‘ is 50, the segment will extend beyond the screen. In fact, it will exceed the screen boundaries even with smaller values, because the ‘target‘ is based on half the screen height while the ‘width‘ is based on the entire screen ‘width‘.

So, for this problem, we define the top wall as the minimum between the height of the screen and the ‘target‘ plus half the gap from the ‘width‘. Similarly, the bottom wall is defined as the maximum between the bottom of the screen and the ‘target‘ minus half the gap from the ‘width‘.

This issue can also occur if the next segment’s ‘target‘ and ‘width‘ stay within the screen boundaries, but the start of the segment does not. For example, if in segment $i$, the ‘target‘ is 80 and the ‘width‘ is 20, the top wall is close to the upper boundary of the screen. However, if in segment $i + 1$, the ‘target‘ is 0 and the ‘width‘ is 60 (which is valid by itself), the top wall of this segment will exceed the previous top wall.

This adjustment may deviate slightly from what the therapist defined in the file, but it is necessary for the game to correctly build the world without segments extending beyond the screen.

During our exploration of the tunnel-building process and handling screen overflows, we discovered an alternative method to define the ‘target‘ and ‘width‘ when the segment exceeds the screen boundary:

$$Target = 100 - (Target + Width - 100)$$

$$Width = 50 - \frac{Target}{2}$$

The first equation removes the excess from the ‘target‘, while the second adjusts the ‘width‘ to fit exactly within the screen's top or bottom boundary. Since the ‘width‘ is a percentage of the entire screen, simply adjusting the ‘target‘ is insufficient.

We derived the second equation from the following condition, which ensures the segment aligns perfectly with the boundary:

$$\frac{Target}{100} \times HalfScreenHeight + \frac{Width}{100} \times ScreenHeight = HalfScreenHeight$$

This process uses absolute values, and afterward, we adjust if the ‘target‘ was negative.

With this approach, the ‘width‘ may result in values smaller than 20. If this happens, the target needs to be reduced, and the excess should be added to the ‘width‘ until it reaches at least 20.

While this solution is more elegant in how it constructs the tunnel, it can lead to significant deviations from the therapist's requirements, so we opted for the first solution.

## 4.2 The Game Scene

After completing the settings scene and pressing the ”Save” button to store the data, the player returns to the main menu. From there, they can either view a tutorial about the game or start playing. When the player presses ”Play,” the game begins. The mouse is placed in the first segment, which is automatically added to all CSV files used as input, providing an easy start to the game.

During the game, the mouse can collide with the tunnel up to five times before losing. Each time the mouse collides with the tunnel, it becomes invulnerable for five seconds.

The game includes four types of bonuses for the player:

- **Get Smaller** – Shrinks the mouse for five seconds.
- **Health** – Adds one life to the mouse.
- **Slow Mouse** – Slows down the mouse for five seconds.
- **Invulnerability** – Makes the mouse invulnerable for five seconds.

The bonuses are placed randomly throughout the world, but there are never more than one-third the number of bonuses as there are segments. Additionally, at the request of the therapist, to encourage the player to stay near the center of the tunnel, all bonuses are placed in the center of the tunnel.

## 4.3 Additional Components

In addition, there are audio components in the game. There are two types of audio:

- **Loop Audio** – This type of audio plays continuously while the game is running. It is present in the main menu scene, game scene, and settings scene.
- **Feedback Audio** – This type of audio provides feedback to the player during game-play. It plays when the mouse collides with the tunnel, collects a bonus, or other similar events.

# 5 Evaluation Of The Game Performance Through Patient Trials

## 5.1 Experimentation

### 5.1.1 Patient Participation and Methodology

Before conducting the experiment, we collaborated with the doctor who guided us throughout the year to ensure the game was optimally designed for the patients. The doctor explained that a patient's level of functionality could vary from day to day, making it difficult to predict their performance in advance. One of the key factors in a patient's success is their sense of achievement and motivation to progress. Therefore, it was essential to develop a dynamic game that adjusted in difficulty and responsiveness to the forces applied by the patient. The game was developed to meet these requirements. Throughout the experiment, the patient played the developed game.

### 5.1.2 Experiment Procedure

1. **Participant Selection:** On the day of the experiment, we invited the participant.

2. **Gameplay and Feedback Collection:** the doctor Assess the participant functional level and adjusted the parameters of the new game (e.g., force, speed, and finger movement precision) to match her ability. We observed the participant engaging with the new game and tackling its challenges based on the assessed functionality.

3. **Post-Game Evaluation:** Upon completing the game, the development team conducted interview with the participant to gather feedback on the respective game. This feedback provided valuable insights into the effectiveness of the game.

The experimental procedure was designed to ensure comprehensive evaluation of the game and to gather actionable feedback for ongoing improvements, ultimately aiming to enhance the therapeutic experience for patients.

## 5.2 Impressions from the Doctor

The experiment was conducted in collaboration with Dr. Shay. During the trial, Dr. Shay appeared satisfied with both the patient's responses and the level of force they were able to exert while playing our game. Dr. Shay observed that the patient's efforts were notably more pronounced and their motivation was higher, which in turn led to improved performance. Patients were able to engage with the game for longer periods of time and demonstrated a greater interest and willingness to continue playing, a significant improvement compared to their experience with the previous game. Dr. Shay expressed approval of the game's dynamic nature. The ability to adjust the difficulty level for each individual patient was essential and provided valuable insight into each patient's progress in their rehabilitation process. Ultimately, Dr. Shay enjoyed working with the patients using our game and believed that it could lead to better outcomes and offer a more tailored rehabilitation process for each patient.

## 5.3 Feedback and Responses from Patients

**Experiment participant answered during the interview:** "I participated in a gaming experiment where I was asked to play a game while flexing and straightening my index finger. The experience was particularly enjoyable, thanks to the meticulous graphics and the fast response of the interface. The task itself was quite intuitive in terms of muscle activation. However, at the beginning of the experiment it was not clear to me how many attempts I had left. After the experimenter made it clear that I had to follow the "lifeline", it did make it easier for me, but I think that this information should be made clearer to the player in advance. Very quickly I felt a strong desire to succeed in the task, and the practice was fun and challenging, so it definitely contributed to increasing my motivation. Overall, it was a very positive experience. In my opinion, the game could benefit from slight improvements in the user instructions. In addition, I recommend increasing the size of the character in the game (the mouse), as this may make it easier for the players, especially for patients with motor and cognitive disabilities, who are often the main target audience of the game. I was happy to take part in the experiment, and I felt that I contributed to its success. I hope that the game will serve as an important tool in training patients, who need many hours of practice and sometimes find it difficult to find motivation. The gameplay aspect can definitely improve their cooperation and make the process easier.
With regards and appreciation,
Orit Wonderman Bar Sela,Physiotherapist".

# 6 Conclusion

Our experiment with patients at Beit Loewenstein demonstrated that hand training was more engaging and enjoyable when using our game compared to the existing game with the Amadeo device. We were encouraged to see that patients showed significant interest in playing repeatedly, suggesting that our game could be a valuable tool in the rehabilitation process and help sustain motivation during finger training.

However, we identified several areas for improvement. First, enhancing the graphics could significantly improve the user experience, and adding in-game effects for collecting bonuses or transitioning between levels may encourage patients to play more actively. Second, introducing collectible coins would provide a sense of ongoing progression, allowing patients to gather coins over multiple sessions and eventually unlock features such as character enhancements or upgrades to the mouse's burrow, further boosting engagement.

Additionally, we plan to implement a database that records data from both patients and therapists. This feature would enable the game to automatically tailor difficulty based on the patient's performance after several demo games, ensuring the experience aligns with each patient's skill level.