iPROLEPSIS

# D4.4 / The iPROLEPSIS serious gaming suite (alpha version)

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# List of abbreviations

| | |
|---|---|
| API | Application Programming Interface |
| AVE | Average Variance Extracted |
| CR | Composite Reliability |
| DMS | Data Management System |
| DDA | Dynamic Difficulty Adjustment |
| FR | Functional Requirements |
| HCPs | Healthcare Professionals |
| NFR | Non-functional Requirements |
| OS | Operating System |
| PsA | Psoriatic Arthritis |
| PLS-SEM | Partial Least Squares-Structural Equation Modeling |
| QoIT | Quality of Innovative Thinking |
| QoL | Quality of Life |
| SGs | Serious Games |
| TAM | Technology Acceptance Model |
| UR | User Requirements |
| VIF | Variance Inflation Factor |
| WP | Work Package |

# Executive summary

This demonstrator deliverable presents the alpha version of the iPROLEPSIS Games application, outlining its design, development, and implementation processes to date. To explain the iPROLEPSIS Serious Games World, the theoretical and methodological frameworks that guided the ideation, design, and refinement of the games are briefly introduced. Additionally, initial and final storyboards are showcased alongside the creation of high-fidelity prototypes and visual assets, including concept art and 3D models.

This document focuses on the iPROLEPSIS Games application, offering a high-level overview of the system architecture and integration. It provides a step-by-step guide on iPROLEPSIS Games application installation, user login, navigation, progress tracking, and interaction with healthcare professionals. Detailed descriptions of gamification elements, general audio features, and specific game categories—such as Breathing Games and Exergames—are included. These are further supported by technical information on Unity-React Native integration, as well as functional, non-functional, and user requirement checklists.

Future developments and next steps are highlighted, emphasizing the incorporation of user feedback, establishing a cloud-based data management system, developing an adaptation algorithm to enhance personalization, and expanding the game suite to include additional game categories. These categories will feature Sensorimotor Art, Emotional, Dietary, and No-Pain Games, all of which will be integrated into the existing framework.

Subsequent phases will focus on creating a Minimum Viable Product (MVP) for the Serious Games Suite. This MVP will offer personalized gameplay tailored to each player's profile and is scheduled for release as part of Deliverable D4.7 (M34).

# 1 Introduction

Task 4.4, "Serious games development," focuses on creating the iPROLEPSIS serious games suite, which includes an adaptation layer to personalize gameplay based on each player's profile. These games, designed to promote wellness and prevent health decline in Psoriatic Arthritis (PsA) patients, will be integrated into a single app. Developed using Unity 3D, the games are intended to be compatible with smartphones and tablets, supporting skeleton tracking for body movement-based interfaces like Exergames. The development follows an agile, sprint-based co-creation approach, drawing on expertise gained from the i-PROGNOSIS[1] and CovidShield[2] projects.

## 1.1 Document scope

This document presents the alpha version of the iPROLEPSIS Games application, developed under Task 4.4. As a "DEM: Demonstrator, Pilot, Prototype," it includes both a prototype and this report, which outlines the foundation methodology and technical aspects and provides a brief user manual. It addresses the challenges in designing serious games for therapeutic purposes, the methodologies employed, and the integration of user feedback. Additionally, this document serves as a guide for stakeholders, including developers, researchers, and healthcare professionals, aiming to apply serious games to personalized health interventions. The alpha (individual games) version details the current status of user, functional, and non-functional requirements, offering insights into what has been fully or partially implemented and what remains in development. Future updates will be provided in deliverable D4.7, which will feature the Minimum Viable Product (MVP) of the iPROLEPSIS serious gaming suite.

## 1.2 Document structure

Overall, this report is organized into the following sections:

- **Section 1 (Introduction)**: Provides an overview of the report's purpose, scope, and structure to give readers a clear understanding of its contents.
- **Section 2 (The iPROLEPSIS Serious Games World)**: Explores the theoretical and methodological foundations, co-creation process, and visual design elements, including storyboards and high-fidelity prototypes, that support the iPROLEPSIS Serious Games.
- **Section 3 (The iPROLEPSIS Games Application)**: Discusses the technical architecture, user interactions, and key features of the serious games designed and developed to date, including gamification, navigation, and technical requirements.
- **Section 4 (Future developments and next steps)**: Highlights planned advancements, including feedback integration, the establishment of a data management system, personalization algorithms, and the introduction of new serious game categories.
- **Section 5 (Conclusions)**: Summarizes the project's progress, key achievements, and future directions for developing the Serious Games Suite.

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[1] Dias, S. B., Diniz, J. A., Konstantinidis, E., Savvidis, T., Zilidou, V., Bamidis, P. D., ... & Hadjileontiadis, L. J. (2021). Assistive HCI-serious games co-design insights: the case study of i-PROGNOSIS personalized game suite for Parkinson’s disease. *Frontiers in Psychology*, *11*, 612835.

[2] Dias, S. et al. (2020). Smartphone-based biofeedback games for shielding of immune system against COVID-19: the Covidshield game suite design approach. In *Proceedings of the 9th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion* (pp. 93-97).

# 2 The iPROLEPSIS Serious Games World

## 2.1 Theoretical framework

With advancements in technology, there is a growing opportunity to integrate digital health tools in rheumatology care, including serious games (SGs), which offer a non-invasive, non-pharmacological complement to clinical interventions[3]. SGs aim to achieve both therapeutic benefits and entertainment, and research shows they can positively influence health behaviours[4].

Psoriatic Arthritis (PsA), a complex inflammatory disease, presents unique challenges in designing effective SGs due to its varied symptoms. Although research on SGs for PsA is limited, studies on rheumatoid arthritis (RA) show that SGs can improve medication adherence and reduce pain[5]. Understanding how to tailor SGs for PsA patients is essential, particularly how the serious and game components influence their willingness to engage with these games.

SGs can improve patient's quality of life (QoL) by fostering positive experiences, supporting self-actualization, and enhancing social connections[6]. These elements align with positive psychology principles and can be explored through the corresponding constructs in the Technology Acceptance Model (TAM)[7]. From this perspective, a related study was conducted and five hypotheses regarding the interaction between serious and game elements have been explored, aiming to assess how they influence PsA patients' intention to use SGs, namely (see **Figure 1**):

- $H_1$—Characterizing Goal has a significant positive relationship with Methods.
- $H_3$—Media Presentation has a significant positive relationship with Enjoyment.
- $H_2$—Methods has a significant positive relationship with Interactions Technology and Integrations.
- $H_4$— Enjoyment has a significant positive relationship with Interactions Technology and Integrations.
- $H_5$— Interactions Technology and Integrations has a significant positive relationship with Intention to Use.

**Method.** PsA patients were recruited from different centres (The Netherlands, UK, Portugal, and Greece) between July and September 2023 through outpatient clinics and social media. Participants were required to provide informed consent and complete a Web survey (see deliverable D2.1), which was translated into multiple languages using a thorough translation and validation process.

The Web survey, developed based on the TAM and SGs quality criteria, consisted of 23 questions covering key determinants of the SG experience and demographic and clinical

[3] Abd-Alrazaq A, Abuelezz I, Al-Jafar E, et al. The performance of serious games for enhancing attention in cognitively impaired older adults. npj Digit Med 2023;6:122.
[4] Caserman P, Hoffmann K, Muller P, et al. Quality criteria for serious games: serious part, game part, and balance. JMIR Serious Games 2020;8:e19037.
[5] Pouls BP, Bekker CL, Gundogan F, et al. Gaming for adherence to medication using ehealth in rheumatoid arthritis (GAMER) study: a randomised controlled trial. RMD Open 2022;8:e002616.
[6] Argenton L, Pallavicini F, Mantovani F. Serious games as positive technologies. In: Cruz-Cunha MM, Reis LP, Martinho R, eds. Handbook of research on applied e-learning in engineering and architecture education. Hershey, PA: IGI Global, 2016:114-32.
[7] Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Q* 1989;13:319-340.

information. Content validation included feedback from diverse stakeholders, such as health professionals, game developers, and patient research partners.

Data were analysed using Partial Least Squares-Structural Equation Modeling (PLS-SEM)[8] to validate the predictive model and assess relationships between constructs. Reliability and validity were tested using Cronbach's $\alpha$, Composite Reliability (CR), and Average Variance Extracted (AVE). The model's structural assessment included path significance, effect sizes, and predictive relevance using multicollinearity analysis and Bootstrap testing. A multi-group analysis explored the influence of factors like gender, education, and technology beliefs.

**Results.** This study included 381 PsA patients, with most being female (64.3%) and aged between 50 and 69 years (57%). The majority had a bachelor's degree (33.7%) or Upper Secondary education (24.9%). The Netherlands had the highest number of respondents (41.7%), and most participants were diagnosed with PsA in the last one to nine years.

*Reliability and Validity:* The survey constructs showed high reliability and validity, with item loadings, Cronbach's $\alpha$, and AVE exceeding necessary thresholds, confirming both convergent and discriminant validity. The path coefficients were significant ($p < 0.05$), and the adjusted $R^2$ values supported the model's hypotheses.

*Multicollinearity and Predictive Relevance:* Multicollinearity was not an issue, with Variance Inflation Factor (VIF) values below 3.3. The effect sizes ranged from moderate to substantial, indicating strong relationships between most constructs. Predictive relevance ($Q^2$ values) was confirmed for all variables.

*Multi-group Analysis:* No significant group differences were found in the primary paths of the model across gender, education, technology dependence, country, age, and years with PsA, except in specific cases. For example, path invariances were noted for certain education levels, low and medium technology dependency, and certain age groups and countries.

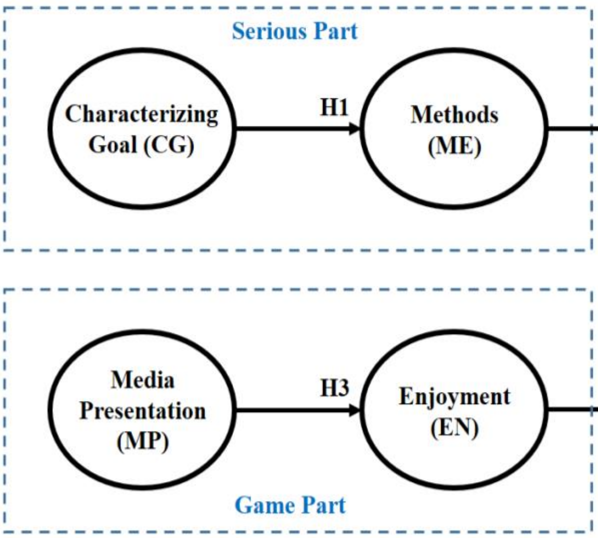



**Figure 1** The proposed framework and corresponding hypothesis (H1-H4).

Results supported all driving hypotheses, with path invariance to patients' characteristics and $H_5$ displaying the highest significance and path loading. This suggests that balanced mediation

[8] Sarstedt M, Ringle MC, Hair JF. Partial least squares structural equation modeling. In: Homburg C, Klarmann M, Vomberg A, eds. Handbook of market research. Cham: Springer International Publishing, 2021:587-632.

and integration of the serious and game parts of the SG by its interactive technology could strongly influence the intention of PsA patients to use SGs as alternative non-pharmaceutical intervention.

This study introduces a model that explores the relationships between the structural elements of SGs — both the serious (goals, methods) and game (media, enjoyment) components — and PsA patients' intention to use SGs. The results show that a well-integrated interaction technology strongly influences patients' willingness to use SGs as a non-pharmaceutical treatment for managing their symptoms. **Both the entertainment value and clinical relevance of SGs are key factors, with interaction technology and integration explaining 76.5% of the variance in intention to use SGs.**

The findings highlight the potential of SGs to enhance PsA management by balancing engagement and therapeutic value. Healthcare professionals should prioritize SG interaction technology when recommending SG-based interventions, focusing on both entertainment and clinical benefits. SGs can offer a range of emotional, cognitive, and social benefits, supporting positive psychology and cognitive-behavioral therapies. They also have the potential to enhance patient education, engagement, and outcomes.

In addition to the results presented in this section, more detailed findings have been prepared for submission in 2024: Dias, S. B., Ramalho, B., Luime, J., Tchetverikov, I., Coates, L. C., Rodrigues, A. M., Dimitroulas, T., Charisis, V., & Hadjileontiadis, L. J. (2024). Determinants of patients' intention to use serious games in psoriatic arthritis: A partial least squares structural equation modeling approach. The related targeted journal is the Lancet Digital Health.

## 2.2 Agile co-creation methodological framework

In the development of emerging health technologies, it is crucial to leverage the experiences of end-users by involving them actively throughout the design process. This approach, known as co-creation, engages stakeholders such as patients, healthcare professionals (HCPs), and researchers from the early stages of product development[9]. By treating end-users as equal partners, co-creation integrates their insights into the ideation, design, and testing phases of new solutions, fostering collaboration and innovation. This methodology allows developers to align products with the actual needs of users, ensuring greater relevance and effectiveness in the final outcome[10].

The iPROLEPSIS project follows an agile co-creation framework, an iterative development methodology that emphasizes flexibility, collaboration, and continuous improvement. In the agile approach, project development is organized into sprints—short, time-bound periods focused on completing specific tasks such as design, development, testing, and deployment. For the iPROLEPSIS Games, this approach was adopted, with each sprint focused on a specific game or key functionality. In addition, regular quality checks and weekly internal reviews were also conducted to ensure ongoing refinement and alignment with the project's objectives.

Four co-creation sessions were held between June 2023 and July 2024 to enhance the design of the iPROLEPSIS serious games, in particular:

[9] Palumbo, R. (2017). The bright side and the dark side of patient empowerment: Co-creation and co-destruction of value in the healthcare environment. Springer.

[10] Tessarolo, F., Petsani, D., Conotter, V., Nollo, G., Conti, G., Nikolaidou, M., ... & Konstantinidis, E. I. (2024). Developing ambient assisted living technologies exploiting potential of user-centred co-creation and agile methodology: The CAPTAIN project experience. *Journal of Ambient Intelligence and Humanized Computing*, *15*(5), 2661-2676.

- **Co-Creation #1** (June 21, 2023): This session, part of the 2nd Plenary Project Meeting (Workshop #3), included 33 participants from nine countries representing industry, research, healthcare, and technology sectors. Using the "Crazy 8s" technique[11], participants developed 32 game scenarios, addressing diverse aspects such as exercise, diet, emotional management, and social interaction. These ideas significantly influenced the development of the project's serious games.
- **Co-Creation #2** (October 2 and 16, 2023): Storyboards illustrating each game category were presented during this session to visually support feedback from participants.
  HCPs (October 2): 14 healthcare professionals (HCPs) from clinical centres in the UK, Greece, and Portugal provided feedback on gestures, movements, and clinical relevance in the game designs. They suggested personalizing Exercise Games, refining Breathing Games' duration, and using NoPain Games as pain distractors and memory aids. They also emphasized the importance of including occupational therapists and considering games as digital biomarkers.
  Patients (October 16): 11 PsA patients participated to provide feedback on gestures, movements, and game concepts. They favoured exergames like "The Spy" and suggested removing the time constraint in "Mr. Blue Sky." They preferred a Tamagotchi-style game for dietary games and expressed interest in incorporating exercise and sleep. Emotional games that monitor heart rate were also well-received.
- **Co-Creation #3** (December 12, 2023): A collaborative session during the 3rd Plenary Project Meeting (Workshop #4) brought together 29 participants to review the "The Kite" Breathing Game prototype. Using the 4Ls method (Liked, Lacked, Learned, Longed For)[12], participants praised the game's clarity and simplicity but recommended improvements, such as reducing on-screen elements and enhancing relaxation through sensory cues. Feedback emphasized the need for personalization and a more positive approach to failure.
- **Co-Creation #4** (July 12, 2024): Using initial mockups and high-fidelity prototypes, 47 participants, including patients joining remotely, provided valuable feedback on the iPROLEPSIS mobile app, with a focus on the Breathing games and Exergame categories. The participants appreciated the clarity of the "More Info" feature, the helpful warning messages, and the intuitive calibration process. However, there was debate regarding Breathing games' scoring system and level progression. Additionally, concerns were raised about the positioning of the Exergame device during gameplay.

A structured work plan and comprehensive reports detailing each co-creation activity mentioned above are documented under T2.2 of the project. Moreover, within this agile framework, three scientific publications have been produced, as listed below:

1. Ramalho, B., Vicente, M., Escobar, H., Gama, S., Diniz, J. A., Charisis, V., Hadjileontiadis, L. J., & Balula Dias, S. (2024, Nov). Developing Sensorimotor Art Games for Psoriatic Arthritis using Agile Storyboarding and Game Co-Design Processes. In Proceedings of the 11th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion (DSAI 2024). Nov 13-15, Abu Dhabi, UAE).
2. Ramalho, B., Vicente, M., Escobar, H., Gama, S., Carnide, F., Baptista, F., ... & Balula Dias, S. (2024, June). Developing Exergames for Psoriatic Arthritis using Agile Storyboarding and Game Design Processes. In Proceedings of the 17th International Conference on PErvasive

[11] Knapp, J., Zeratsky, J., & Kowitz, B. (2016). Sprint: How to solve big problems and test new ideas in just five days. Simon and Schuster.
[12] Gottesdiener, E., 2010. The 4L's: A Retrospective Technique. Online. Last accessed on (November 24, 2024). https://www.ebgconsulting.com/blog/the-4ls-a-retrospective-technique/.

Technologies Related to Assistive Environments (pp. 569-575). https://doi.org/10.1145/3652037.3663939
3. Ramalho, B., Vicente, M., Escobar, H., Gama, S., Carnide, F., Baptista, F., ... & Dias, S. B. (2024, June). “The Kite” Breathing Serious Game: Agile Co-Design for Psoriatic Arthritis. In 2024 IEEE 22nd Mediterranean Electrotechnical Conference (MELECON) (pp. 1036-1041). IEEE. https://doi.org/10.1109/MELECON56669.2024.10608739

## 2.3 Game design process ideation

The ideation process for the iPROLEPSIS game design began during the first co-creation session (see section 2.2). The session brought together a multidisciplinary group of 33 participants (17 females), aged 25 to 58, representing various sectors, including industry, research, healthcare, and technology. These participants were organized into four teams: healthcare professionals (HCPs) (Team 1), patients (Team 2), researchers (Team 3), and technical experts (Team 4). The session was structured into a three-phase process to guide the ideation and design of the iPROLEPSIS games (see **Figure 2**), in particular:

- **Phase A - Goal setting and Crazy 8’s technique:** Participants were introduced to the session's objectives and the Crazy 8's technique. Each team brainstormed game ideas across categories like ExerGames, DietaryGames, EmoGames, BreathingGames, NoPainGames, and SensorimotorArtGames.
- **Phase B - Ideation, sketching, and group discussion**: In this phase, participants had eight minutes to generate eight distinct game ideas, sketching them in designated boxes. This encouraged creativity and led to presentations where team spokespersons shared their game concepts.
- **Phase C - Ideas display and voting process**: After sharing ideas, 32 game scenarios were displayed on a wall, and participants voted for the most promising concepts using dot stickers. A consortium-wide discussion followed to select the most popular ideas for further development.

The session, lasting 45 minutes, was designed to foster collaboration and creativity, and purposive sampling ensured the participation of individuals with relevant expertise and perspectives. This ideation process was crucial in shaping the direction of the iPROLEPSIS serious games development.

To explore the quality of innovative thinking (QoIT) within the Crazy 8s acquired sketch data, we have incorporated various dimensions. In particular, three fundamental dimensions/pillars were explored, i.e., (1) the symbolic, (2) content, and (3) dynamic dimensions. More specifically, for the symbolic dimension, various categories were identified, such as universal symbols, cultural symbols, abstract symbols, iconic symbols, and metaphoric symbols, to name some. These categories also indicate potential areas for symbol clustering, both within individual sketches and across the set of eight sketches. Furthermore, beyond their classification, the symbols used can contribute to several properties of the Crazy 8s sketches, including syntactic density, semantic density, and ambiguity. In addition, symbol structural forms were also considered, such as geometric shapes, free-form (or organic) shapes, and linguistic label-like shapes. For the content dimension, Gestalt laws were adopted, including those of simplicity, proximity, similarity, closure, figure and ground, good continuation, and common fate[13]. With regards to the dynamic dimensions across the eight consecutive ideation sections, elements that pertain to the variations and/or similarities across these sections were explored, such as transformation, reinterpretation, causality, and within-group dynamics.

[13] Koffka, K. (2013), Principles of Gestalt Psychology, International Library of Psychology, Taylor & Francis. URL: https://books.google.ae/books?id=tWxHAQAAQBAJ

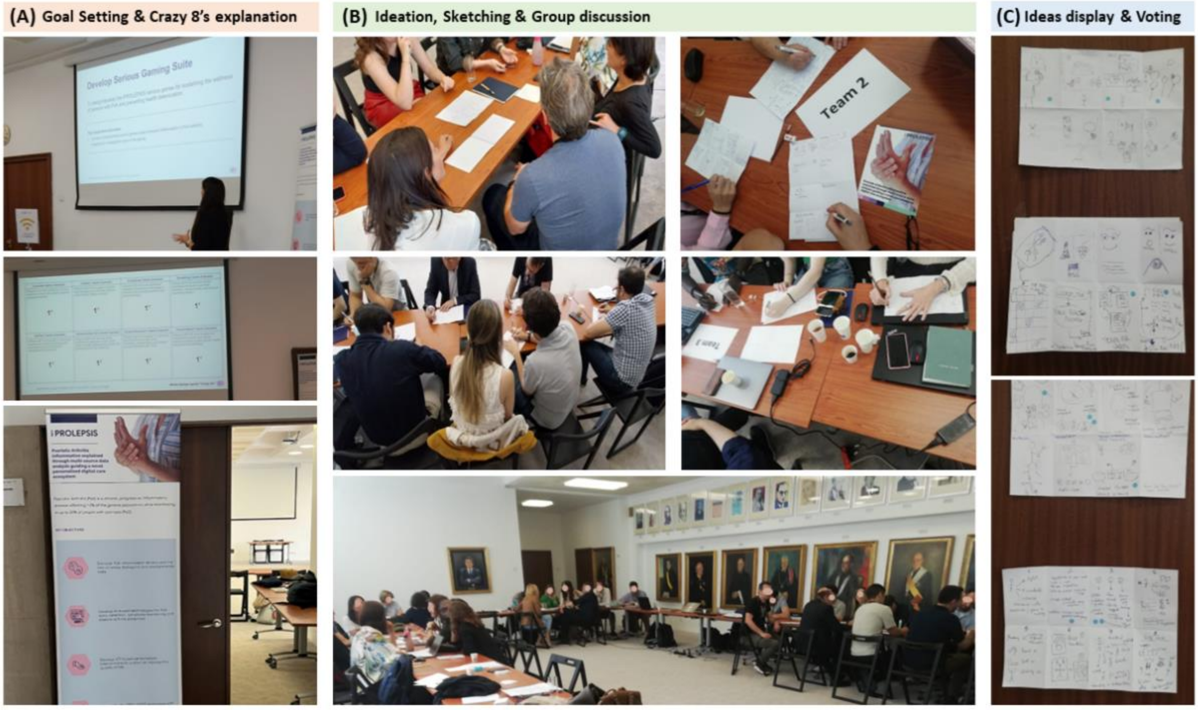



**Figure 2** The first co-creation session for the design of serious games within the iPROLEPSIS concept, including three main phases: (A) Goal setting and Crazy 8's explanation, (B) Ideation, sketching and group discussion, and (C) Ideas display and voting.

In this way, an explainable Crazy 8s framework was established, namely xCrazy 8s. The implementation of the xCrazy 8s involved fuzzy logic with a series of nested fuzzy inference systems (FIS)[14] that can take the data per dimension as input and produce an estimation of the effect of each dimension and the final estimated QoIT. Preliminary results derived from the analysis of the 32 game scenarios using the xCrazy 8s framework reveal the various effects of each dimension that could explain the building of the final QoIT of each sketch per each team (see **Figure 3**).

In addition to the results presented in this section, more detailed findings have been prepared for submission in 2024-2025: Dias, S. B., Ramalho, …, & Hadjileontiadis, L. J. (2024). Fuzzy xCrazy8s: A novel framework for mining Crazy eights towards explainable innovative thinking. The targeted journal is Nature Human Behaviour (*to be submitted*).

[14] Azeem, M. F. (Ed.). (2012). *Fuzzy inference system: theory and applications*. BoD–Books on Demand.

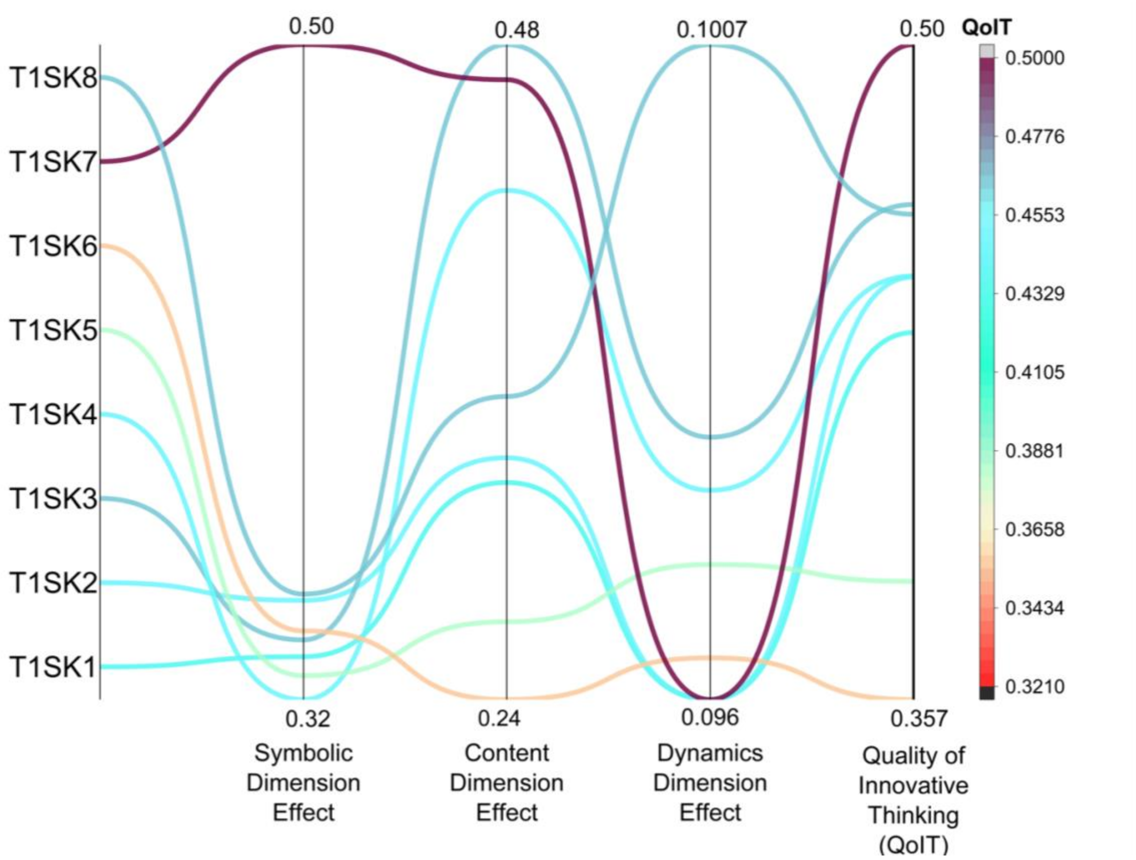



**Figure 3** Example of the preliminary results derived from the analysis of the 32 game scenarios using the xCrazy 8s framework across its dimensions, explaining the building of the final QoIT of each sketch (SK#) for Team 1 (T1).

## 2.4 Storyboards development

### 2.4.1 Initial Set of Storyboards

The first set of storyboards was developed based on feedback derived from the first co-creation session (see section 2.2) and insights from the online survey (refer to Deliverable 2.1), confirming the relevance of six planned game categories for the iPROLEPSIS Personalized Game Suite (see **Figure 4**), as follows:

1. **Breathing Games**
   - Characterizing goal: To promote stress relief and practice breath control to enhance overall well-being and relaxation.
   - **The Kite:** Players control a kite's trajectory by blowing into the smartphone's microphone, earning points for proper breathing cycles.
   - **Star Catcher:** Similar mechanics to The Kite, where players maneuver a rocket to catch stars, reinforcing breathing concepts.
   - **Bubbles:** Aimed at blowing soap bubbles; however, it was considered more of a simulation with insufficient gaming dynamics.
2. **ExerGames**
   - Characterizing goal: Focused on puzzle elements to practice fine motor skills.
   - **Escape:** A platform game with interconnected mini-games that engage players in various hand movements (e.g., dragging, pressing, tapping) while avoiding overexertion.

- **Mr. Blue Sky:** Players rotate containers to transform rainy clouds into white clouds, combining the practice of refined motor skills of the wrist with mental challenges.

3. **Sensorimotor Art Games**
    - Characterizing goal: Designed to stimulate creativity and relaxation.
    - **Illusion Doodle:** Players create optical illusions by drawing steps on a virtual canvas.
    - **One Art:** Involves daily painting of a canvas section, fostering artistic expression over time.
4. **No Pain Games:**
    - Characterizing goal: Aimed at distracting players from pain through engaging, replayable mini-games.
    - **Lighting:** Players tap to follow a sequence of illuminated lamps.
    - **The Garden:** A flower-finding game that progressively increases in difficulty.
5. **Dietary Games:**
    - Characterizing goal: Focused on educating players about nutrition and healthy eating habits through engaging gameplay.
    - Specific games were not detailed in the initial set but aimed to incorporate food-related challenges and healthy choices.
6. **EmoGames:**
    - Characterizing goal: Designed to enhance emotional well-being and resilience through interactive experiences.
    - Like the dietary games, specific examples were not outlined in the initial storyboard but intended to foster positive emotional states and coping strategies.

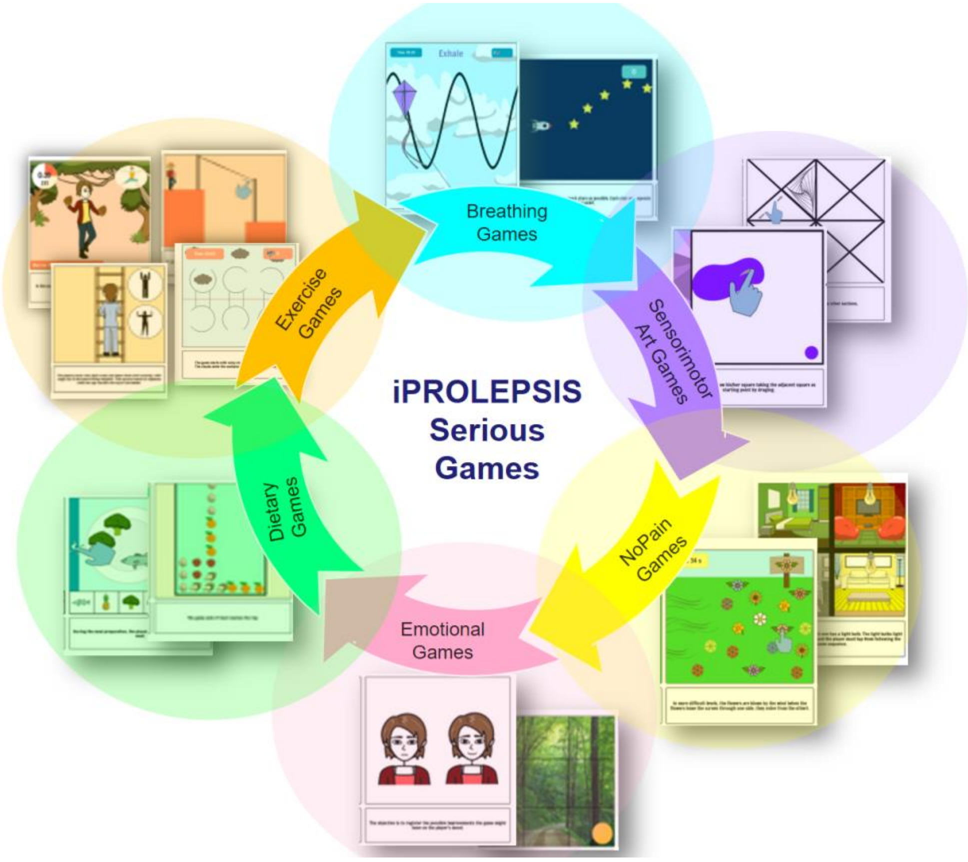



**Figure 4** Final set of storyboards, including 14 game scenarios, namely: two Breathing Games, four Exergames (two fine motor skills Exergames, and two full-body Exergames), two SensorimotorArt Games, two NoPain Games, two Emotional Games, and two Dietary Games.

Overall, feedback indicated concerns regarding the specificity and potential overexertion of the games, highlighting a need for full-body Exercise games (Exergames).

### 2.4.2 Final Set of Storyboards

Based on the feedback from the initial co-creation session and further insights from PsA patients and healthcare professionals in co-creation session #2 (see section 2.2), we iteratively refined the game concepts to develop the final set of storyboards. These storyboards prioritize both engagement and clinical relevance across three main game categories: Dietary Games, EmoGames, and Exergames, as described below.

**Dietary Games**

- **The Food Scientist**: In this Tamagotchi-like game, players take on the role of an astronaut tasked with preparing balanced meals while tracking real-life physical activity using a smartwatch (or playing without one, if unavailable). The player's steps impact the level of support the astronaut receives while preparing meals. Additional mini-games involve station maintenance tasks, which keep gameplay diverse and interactive. This game design aligns with patient feedback, favouring lifestyle-oriented tasks, and offers a fun approach to nutrition and activity monitoring.
- **Up & Down**: Inspired by Snakes and Ladders[15], Up & Down encourages nutritional education by assigning players to dice that vary based on their activity levels. Higher activity levels reward players with more favourable dice, reinforcing healthy habits. The board game includes special squares and mini-games that teach food portion sizes and the Eatwell Plate[16], making the learning experience engaging and interactive. This approach was designed to make nutritional education both accessible and enjoyable.

**EmoGames**

- **The Photographer**: This relaxation-focused game allows players to explore calming landscapes while measuring their emotional state through heart rate (via smartwatch or phone camera). The player, a photographer, captures serene scenes, with each photo session rewarding them with upgraded camera equipment, encouraging replayability. The main objective is to lower heart rate during gameplay, fostering a sense of calm that aligns with the game's health-focused goals.
- **The Quiz**: Combining cognitive engagement with relaxation, this trivia game featuring questions about the various countries included in the project consortium. Correct answers unlock puzzle pieces or colouring options for soothing images. After each quiz session, players can check their emotional state using face capture, aiming to see an improvement in mood. The relaxing images can be accessed anytime in a gallery, providing an ongoing incentive for relaxation and engagement.

**Exergames**

- **The Spy**: A full-body exergame where players, acting as spies, navigate through obstacles using both arm and leg movements to escape a villain's lair. This game received positive feedback from patients who found the full-body movements enjoyable and engaging. The fun, action-oriented approach was particularly appreciated, as it combined physical activity with entertainment in an immersive experience.
- **The Zen Forest**: Developed as a second full-body Exergame, The Zen Forest focuses on stretching exercises inspired by yoga and Pilates to target symptoms like morning

[15] https://play.google.com/store/apps/details?id=ir.Hadiware.Snake_Ladder&hl=en
[16] https://www.nhs.uk/live-well/eat-well/food-guidelines-and-food-labels/the-eatwell-guide/

stiffness and inflammation. The game guides players through a series of warm-ups, main exercises, and cool-down stretches. Players interact with a virtual forest environment that grows and transforms with each completed exercise. Sound cues, such as chirping birds and gentle wind, guide the player's movements, making the experience both immersive and accessible.

The final storyboards result from an iterative process shaped by feedback from PsA patients and healthcare professionals, ensuring the games are engaging and clinically relevant. This user-centered approach has led to a suite of enjoyable and health-focused games, promoting physical and emotional well-being for PsA patients. The evolution from initial to final storyboards highlights a commitment to incorporating user insights, creating games that entertain while supporting players' health. The overview of the final set of storyboards is presented in **Figure 4**, and detailed descriptions are available in Appendix 1. Storyboards

## 2.5 High-fidelity prototypes

After defining the game concepts, high-fidelity prototypes were developed in Figma[17] for both the individual games and the main iPROLEPSIS Games app, with attention to a cohesive user interface (UI). Initially, each game category was distinguished by color-coded backgrounds, but this approach evolved into a refined gradient effect for a more modern, clean appearance (see **Figure 5**). The first prototype, "The Kite" Breathing Game, set the design foundation for the entire app. Usability improvements included replacing drop-down menus with buttons to simplify navigation. The difficulty levels in "The Kite" Breathing Game were restructured to make progression clearer, labeling them with terms like "Beginner Level" alongside breathing patterns (see **Figure 6**). Difficulty levels are unlocked through gameplay to encourage user engagement. The tutorial was also redesigned as a full-screen guide with intuitive navigation (see **Figure 7**).


**Figure 5** High-fidelity prototypes of the Games' Category Menu (1st and 2nd versions).

[17] https://www.figma.com

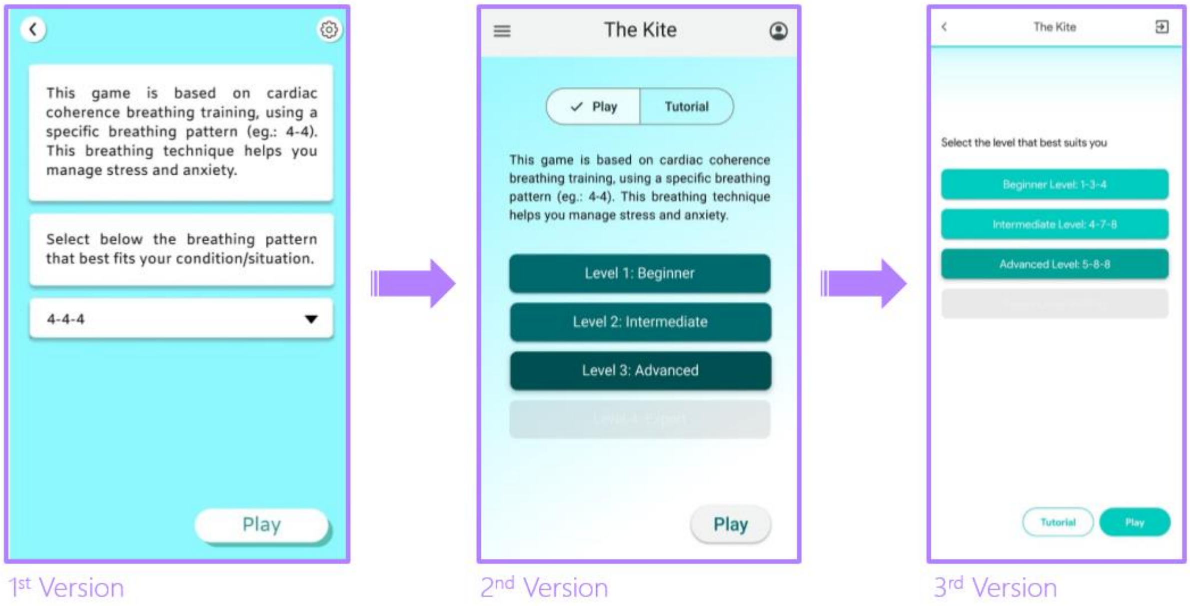



**Figure 6** High-fidelity prototypes of the difficulty levels in the Breathing Game (from 1st to 3rd versions).

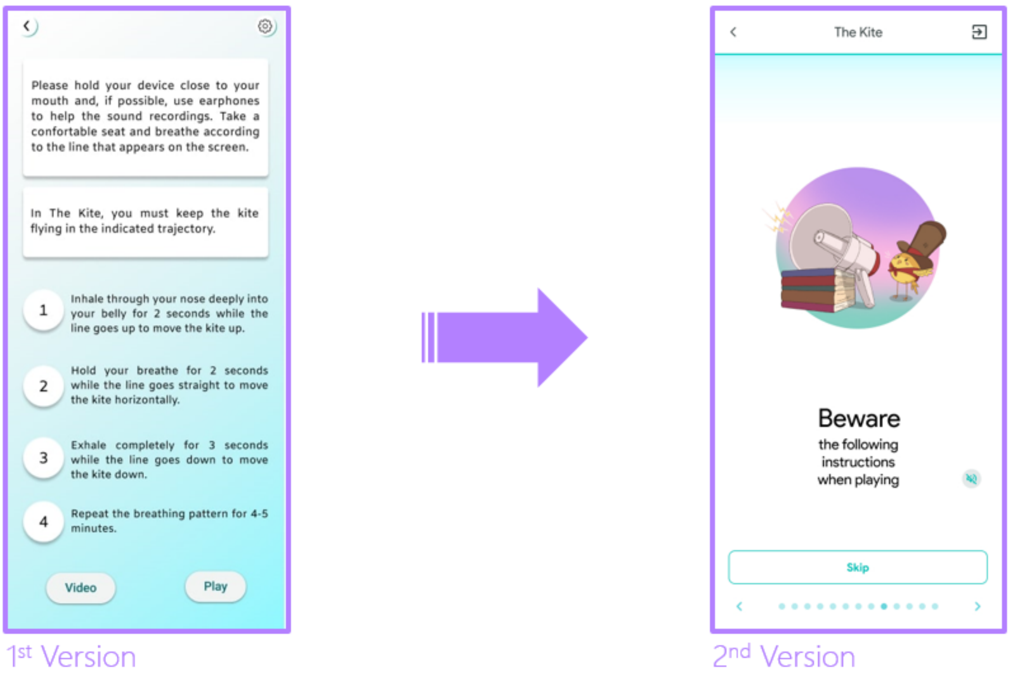



**Figure 7** High-fidelity prototypes of “The Kite” Breathing Game tutorial (1st and 2nd versions).

Using the Material Design 3 (MD3) framework[18], the iPROLEPSIS Games app achieves a cohesive, professional look with minimalist UI elements like time, score, and breathing feedback.

Post-game screens display motivational messages and provide clear performance summaries, offering personalized feedback based on score levels. Stress levels intended to be collected via smartwatch are displayed before and after gameplay to enhance clinical relevance. This transitioned from a bar to a circular display to better fit smartwatch formats

[18] https://m3.material.io/

(see **Figure 8**). Stats on breathing cycle accuracy are presented in an accessible carousel format, allowing users to review their performance without feeling overwhelmed.


**Figure 8** High-fidelity prototypes of the Stats for the Breathing Game "Kite" (1st and 2nd versions).

Additionally, based on feedback from co-creation sessions #3 and #4, further design refinements were incorporated into the iPROLEPSIS Games app, as outlined below:

1. UI enhancements:
    - Added a loading screen with a subtle fade of category colors to strengthen brand recognition.
    - Developed a user authentication screen styled consistently with the miPROLEPSIS app, supporting sign-in via User ID and password, with email login planned for future updates.
    - Redesigned the categories menu, replacing chips with square tiles, each featuring unique colors, icons, and descriptions.
2. Expanded Home Menu:
    - Added Home (games access), Calendar, and Stats sections, with a “Games” button linking to Unity-powered games.
    - A "flare-up" indicator feature was initially considered, but ultimately moved to the miPROLEPSIS app for better clinical data integration.
3. Additional features:
    - A "More Info" button offers scientific information with a streamlined layout, icons, and text-to-speech support.
    - The tutorial was enhanced with step-by-step illustrations and optional text-to-speech for a user-friendly experience.
4. Game-specific design adjustments:
    - Positioned Star Catcher, a breathing game, as an introductory level to help players ease into the gameplay.
    - Adapted full-body Exergames to fit within app constraints, addressing technical challenges of browser-based implementation.
5. Smartwatch integration:

- Consistent design elements were applied to smartwatch connectivity screens, aligned with miPROLEPSIS standards, to facilitate data collection, such as stress levels.

These updates, based on feedback from users and relevant stakeholders, enhance the iPROLEPSIS Games app by providing a seamless, accessible, and engaging experience with intuitive navigation, personalized health insights, and a design that caters to diverse user needs and preferences.

## 2.6 Visual Assets

The visual assets were initially inspired by the overall design of the miPROLEPSIS app. As high-fidelity prototypes were developed, these assets were created simultaneously to ensure a cohesive aesthetic across both the miPROLEPSIS app and the iPROLEPSIS Games. Concept art was initially created to establish a unified visual style, while still allowing each serious game to maintain its distinct look. The 3D models were then developed based on this concept art, as detailed in the next subsections.

### 2.6.1 Concept Art

Concept art was developed based on predefined scenarios, objects, and characters to create a cohesive and original "iPROLEPSIS World" (including characters, objects, and environments). To achieve this goal, tools like Blender were utilized for 3D modeling. The choice of colors and textures was guided by principles of accessibility and therapeutic design, ensuring visual elements support user engagement and relaxation. More specifically, a colour palette aligned with the iPROLEPSIS project's branding was also considered (see **Figure 9**, refer to D6.1). Base colours were used for the scenarios, while distinct colors were applied to characters and key objects to enhance their visibility.

Additionally, the iPROLEPSIS Serious Games logo was designed, blending the miPROLEPSIS app's aesthetic with a playful element to reflect the spirit of the games (see **Figure 10**).


**Figure 9** iPROLEPSIS project colour palette

**Figure 10** iPROLEPSIS Games logo

### 2.6.2 3D Assets and modelling process

Following the creation of the concept art, the 3D assets were modeled in Blender[19] for integration into Unity 3D[20]. These assets were developed with performance optimization in mind while adhering to the artistic direction outlined in the concept art.

#### 2.6.2.1 The Kite

**The Kite Breathing game.** The kite model underwent several iterations to resolve design and performance issues. Initially, the kite was constructed from multiple pieces, but this approach caused gaps between elements. The final solution involved simplifying the kite to fewer pieces, modeled efficiently for Unity's environment. The kite's dynamic movements were simulated in Unity 3D, with wind oscillation effects added for realism (see **Figure 11**).

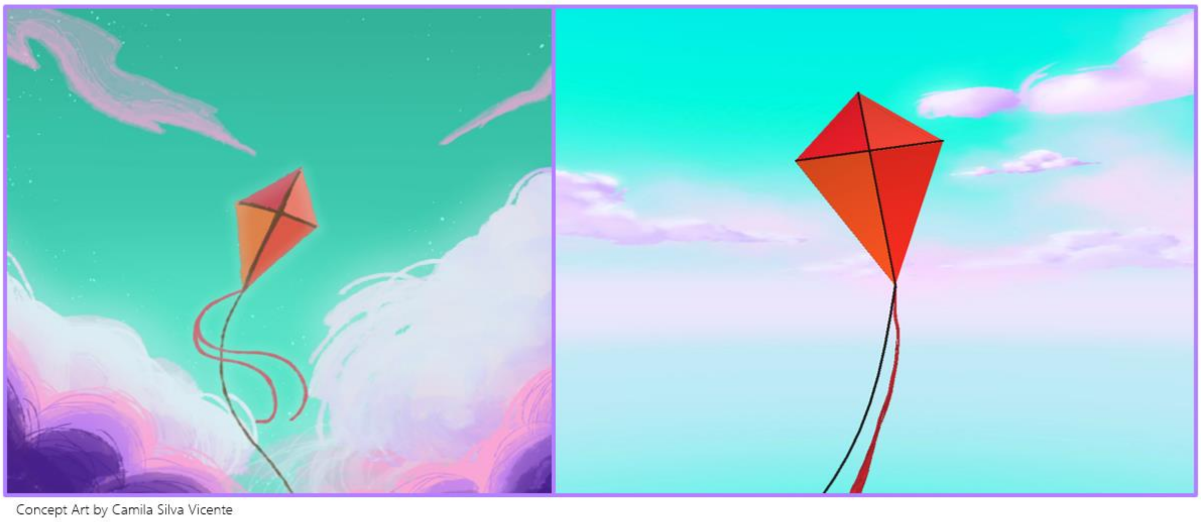



**Figure 11** The concept art (left) and 3D model (right) of the Kite for the Breathing Game "The Kite".

#### 2.6.2.2 Star Catcher

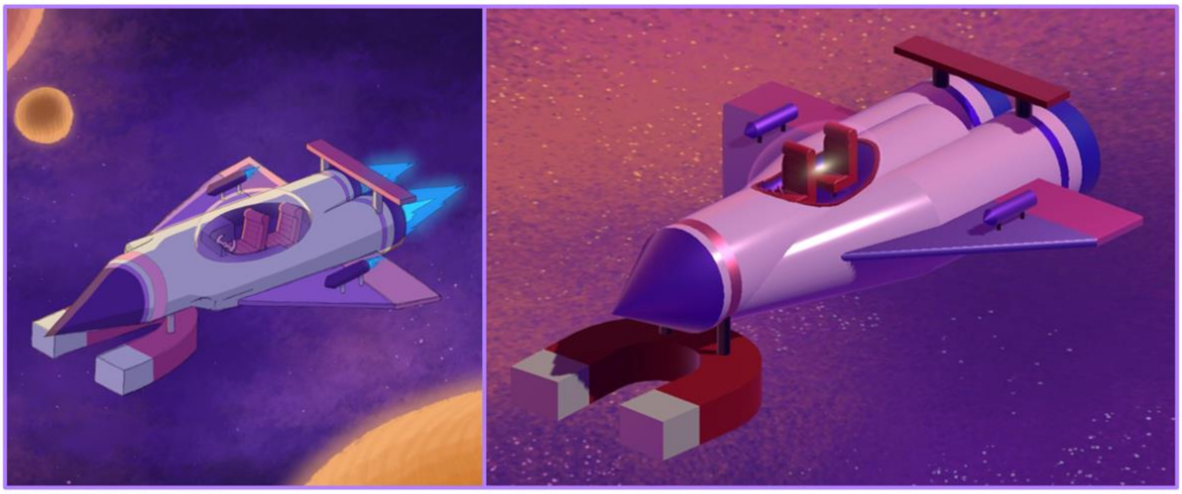
**Star Catcher Breathing game.** For this serious game, a more complex set of assets was required, including:

- **Planets**: Modeled based on the concept art, including designs for a black hole, cloudy planet, crashed planet, and a ringed planet. Certain features, like the black hole and clouds, had to be recreated in Unity due to export limitations from Blender (see **Figure 12**)
- **Spaceship and stars**: The spaceship and stars were modeled using basic shapes and enhanced with texturing in Unity (see **Figure 13**).
- **Home planet**: A procedurally generated terrain, complete with buildings, trees, and lakes, added depth to the game world (see **Figure 14**).

[19] https://www.blender.org/
[20] https://unity.com/

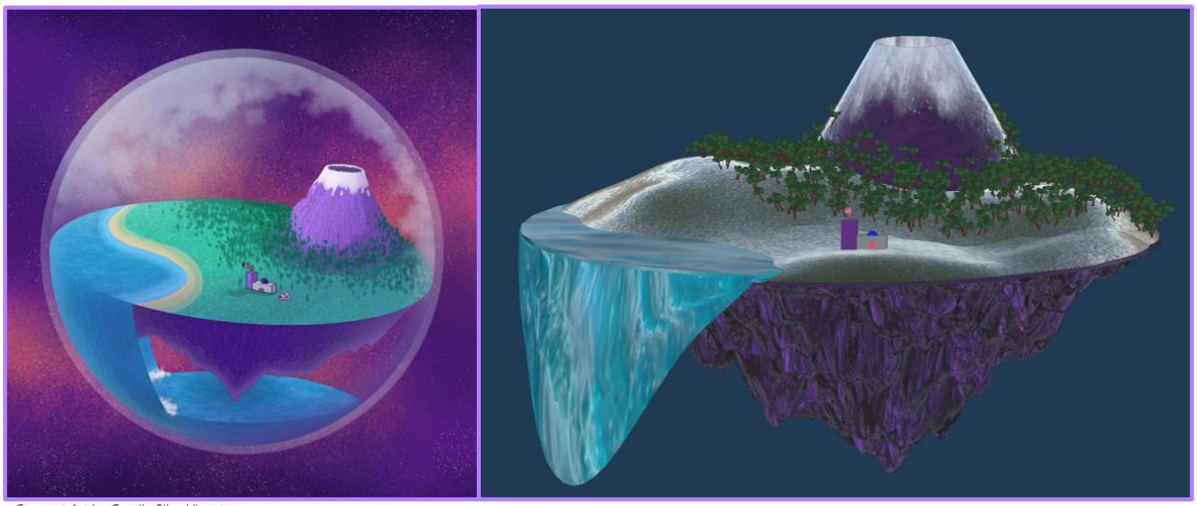
Concept Art by Camila Silva Vicente

**Figure 12** The concept art (left) and 3D models (right) of the planets for the Breathing Game "Star Catcher".



Concept Art by Camila Silva Vicente

**Figure 13** The concept art (left) and 3D models (right) of the spaceship for the Breathing Game "Star Catcher".



Concept Art by Camila Silva Vicente

**Figure 14** The concept art (left) and 3D models (right) of the Home planet for the Breathing Game "Star Catcher".

### 2.6.2.3 Mr. Blue Sky

**Mr. Blue Sky Exergame:** Simpler assets such as pipes, portals, and clouds were created. Pipes were modeled with a focus on rotational consistency, while portals featured the iPROLEPSIS logo for branding. Clouds were dynamically generated in Unity 3D using the Particle System to add movement and variation to the game environment (see **Figure 15**).


Concept Art by Camila Silva Vicente

**Figure 15** The concept art (left and center) and 3D models (right) for the Exergame "Mr. Blue Sky".

### 2.6.2.4 Escape

**Escape Exergame.** The development of the "Escape" Exergame involved creating multiple assets for various mini-games. Each mini-game required unique assets, with the lock being the first asset modeled. This involved designing the lock's basic shape, adding details like grooves, numbers, and a rounded top for realism. The platforms were then created, consisting of parallelepipeds with scattered plants (ferns and monsteras) and crystals, all of which were procedurally generated using Geometry Nodes. The plants were assigned random colors, while the crystals followed a gradient, denser at the bottom and fading towards the top (see **Figure 16**).

The puzzle elements included in the game were simpler, relying more on 2D images, with pieces shaped as squares for consistency. The puzzle was framed, and the cards for a memory game were created similarly with images on both sides. The obstacles included a stalactite, which was modeled with a cone shape and added relief, and a stone carved with runes, featuring a hidden "Birb is king" message as an Easter Egg. The stones were created with irregular shapes, displacement for texture, and materials for glowing runes. In addition, to incorporate the mini-games into the world, a wooden table was modeled to place these challenges on, with adjustments to textures for better game-world integration. A lock door was also modeled, with a rock frame and a sci-fi door design, featuring a baked texture to ensure compatibility with Unity. The door and lock were parented for movement within the game. The clues to escape the cave were designed as a post-it note inside a crystal. This involved combining textures for the note and its scribble, with a transparent, metallic crystal material. The final elements of the game, including the background skybox, were planned but faced issues with integration into the game world, especially regarding visibility of the painted cave walls. The final 2D/3D models created for this game are displayed in **Figure 17**.

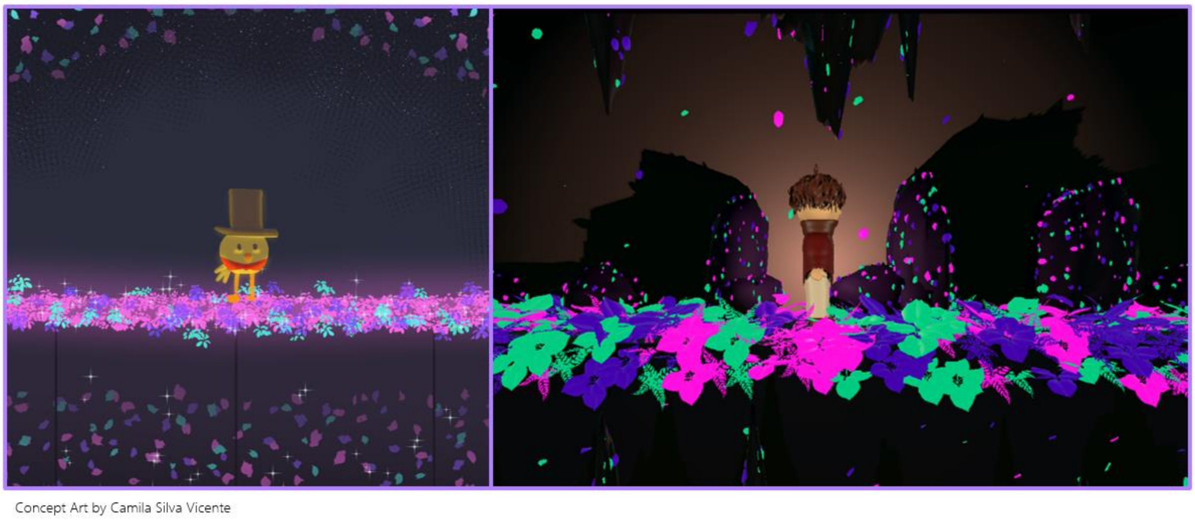



**Figure 16** The concept art (left) and 3D models (right) for the Exergame "Escape”.

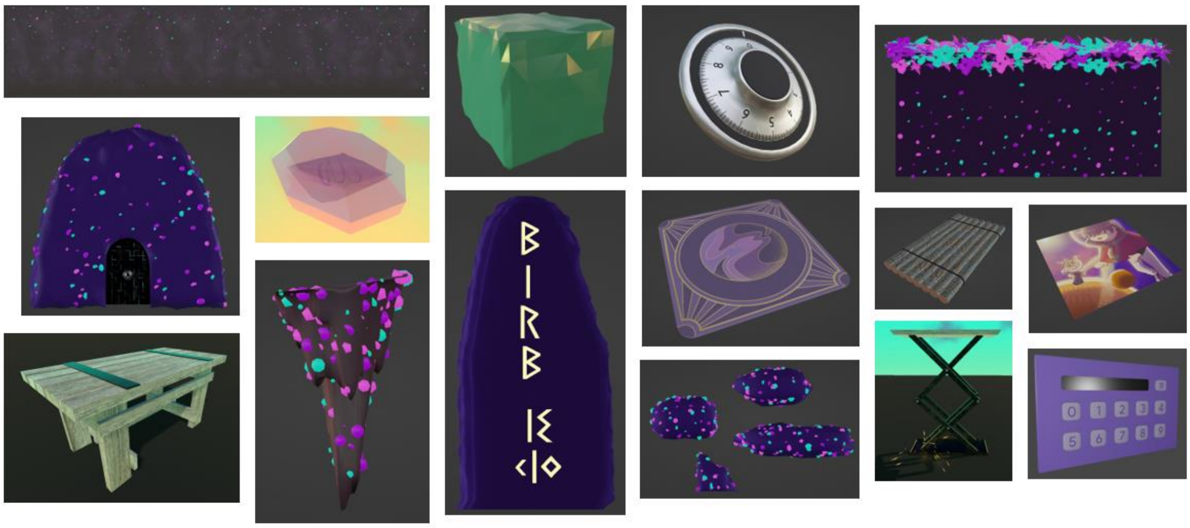


**Figure 17** Original 2D/3D models created for the Exergame 'Escape', including the lock, platform, stalactite, rune stone, crystal block, wooden table, locked door, clue, wall, raft, scissor elevator, and keypad lock.

### 2.6.2.5 Characters

The character modeling for the main figures in the iPROLEPSIS Games is detailed below, showcasing the steps in creating and animating each character to enhance both visual appeal and game performance.

- **Birb**: The character creation began with a low-poly model based on concept art. This involved starting with a cube and refining it by adding geometry, especially around joints for flexibility. Afterward, a high-poly model was created to add finer details, like bevels, extrusions, and sculpted fabric folds. The high-poly model's details were baked into textures to optimize performance. For texturing, UV maps were unwrapped, and texture grids and ID materials were used before baking the textures manually in Blender. The textures, including ambient occlusion and normals, were then transferred to Quixel Mixer for further refinement. A floating platform for Birb was modelled using an extruded cylinder with emissive material properties (see **Figure 18**).

- **Animation**: Birb was rigged with an armature (skeleton), and bones were added for each body part, including the beak, head, hips, legs, feet, tail, and wings. The model was then "skinned," where each bone was manually assigned weights through weight painting. Animations for Birb included idle, wing opening/closing, and wing waving, which were constructed to allow for scalable movements. For facial expressions, 2D images were used for the face, and their animations were controlled by a combination of materials and bones in Unity (see **Figure 18**).


**Figure 18** The concept art (left) and 3D model (right) of the main character, Birb.

- **Kel**: Kel's modelling followed similar steps but included more complexity due to interchangeable outfits (summer and winter) and a more natural-looking head sculpted instead of extruded. The hair was stylized using path and circle curves, and multiple textures were baked for different outfits. During skinning, weight adjustments had to be made for both the summer and winter outfits, and challenges arose with skinning adjustments affecting both outfits. Kel's facial expressions were managed similarly to Birb, with 2D drawings animated and synchronized between Blender and Unity, though some challenges were faced with exporting animations for facial expressions (see **Figure 19**).


**Figure 19** The concept art (left) and 3D models (right) of the main character, Kel, shown in both summer and winter outfits.

This streamlined workflow incorporated thorough processes for modeling, retopologizing, high-poly mesh creation, UV unwrapping, texture baking, rigging, skinning, and animating each character (see **Figure 20**). Each step was executed to ensure that both Birb and Kel were visually appealing while remaining highly optimized for game performance. This approach allowed for fine details in the characters' appearance and movements, enhancing their expressiveness and fluidity while maintaining efficient resource usage essential for a smooth gaming experience.

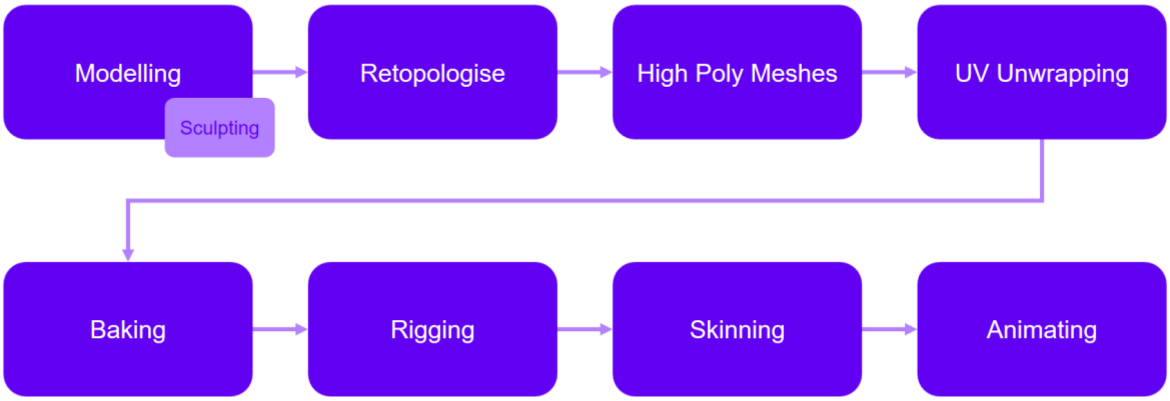



**Figure 20** Workflow illustrating the detailed processes for character creation, including modeling, retopology, high-poly mesh creation, UV unwrapping, texture baking, rigging, skinning, and animation.

# 3 The iPROLEPSIS Games Application

## 3.1 System high-level architecture and integration overview

Initially, we planned to develop several standalone games in Unity, each of which would later be integrated into the main application built in React Native. The idea was to provide flexibility for independent game development, allowing us to update or modify individual games without impacting the overall application. However, as development progressed, we encountered significant challenges with integrating multiple Unity games into the React Native[21] app. These included compatibility issues, challenges with data management, and the complexity of coordinating interactions between the separate components of the system. To overcome these challenges and streamline the development process, we revised our approach and decided to consolidate all games into a single Unity project. This new architecture allowed us to simplify the integration process and minimize the technical difficulties encountered previously. With this unified structure, the main application now serves primarily as a launcher for the combined Unity project, which then manages all the game-related functionalities internally.

Unity now handles a wide range of essential tasks, including game selection, storage of information about each serious game, and user data collection. This consolidation allows Unity to gather data on user interactions, gameplay performance, and engagement metrics. Moreover, Unity facilitates the storage and processing of in-game data, which can be used to track user progress, preferences, and overall behavior during gameplay.

The integrated Unity project also manages the process of uploading data to the iPROLEPSIS Database. As users interact with the games, the app collects real-time data on user activities, game performance, and responses. These data are then securely uploaded to the central database for further analysis, providing valuable insights into user behavior, game effectiveness, and areas for improvement. The data upload process is automated, ensuring a seamless flow of information between the games and the backend system.

In this new architecture, the app is no longer responsible for managing game flow, data collection, or user interactions. Instead, it functions as a launcher, allowing the Unity project to handle all internal tasks, including user interaction, game logic, data storage, and data upload. This approach simplifies the overall development and integration, reduces the need for complex interactions between Unity and React Native, and ensures a more efficient and effective system. **Figure 21** presents an overview of the high-level architecture, showing the interactions between the iPROLEPSIS DMS, iPROLEPSIS Games Application, and the Game Suite.

[21] https://reactnative.dev/

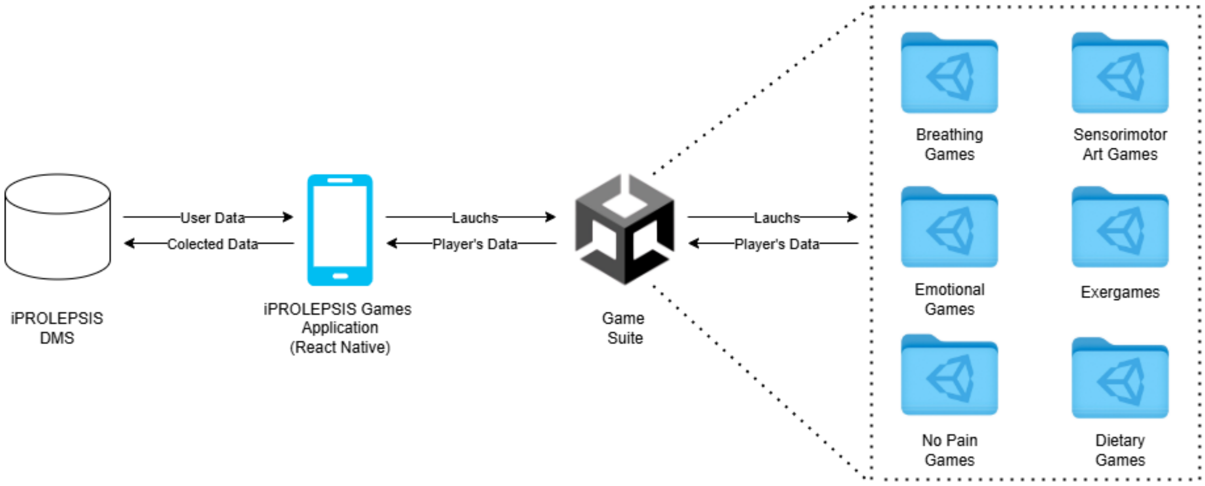



**Figure 21** High-level architecture of the system.

This integration process is designed to combine data from multiple sources, such as the miPROLEPSIS patient app and wearable devices (Garmin Vivoactive 5), with the goal of enhancing the gaming experience and providing real-time insights into the user's health status during gameplay. By collecting both user profile information and real-time physiological data, we aim to personalize and adapt the games to each individual's specific needs and current health condition, ultimately improving the effectiveness of the intervention.

## 3.2 Using the application

This section presents a user manual for the iPROLEPSIS Games application, outlining each feature in a step-by-step format with visual screenshots to demonstrate the navigation flow. The features included in this version were co-designed and co-created in collaboration with iPROLEPSIS medical and technical partners, along with PsA patient research partners. Feedback was gathered through a series of co-creation sessions conducted between June 2023 and July 2024. The user interfaces follow the visual branding established for the iPROLEPSIS project and the miPROLEPSIS app, ensuring a cohesive and recognizable user experience.

The iPROLEPSIS Games app is currently available for Android and will eventually be released for iOS. The Android version is expected to be available on Google Play, while the iOS version will be accessible via the App Store.

Currently, the Android version of the iPROLEPSIS Games application can be downloaded from here. You can log in using the test accounts with the following usernames and passwords:

- **Test User 1**
  Username: dev-fmh1
  Password: fmh1123
- **Test User 2**
  Username: dev-fmh2
  Password: fmh2123
- **Test User 3**
  Username: dev-fmh3
  Password: fmh3123

### 3.2.1 How to install the application

To install the iPROLEPSIS Games application, it is expected that two main steps should be followed:

- **Step 1**: The iPROLEPSIS Games app is available for download on both Google Play for Android devices and the App Store for iOS devices[22].
- **Step 2**: Once downloaded, the installation will start automatically, as with other smartphone applications.

#### 3.2.1.1 Minimum Requirements

- **Smartphone:** Android: version 5.1 (API level 22) or higher[23]
- **Tablet:** Android: version 5.1 (API level 22) or higher[24]
- **Wearable:** Garmin VivoActive 5
- **An account** (username and password) should be available, enabling the user to login into the application.

### 3.2.2 User Login

**Step 1:** After installing the application, click the iPROLEPSIS Games icon. The Loading screen[25] will appear, followed by the Login screen (see **Figure 22**).

**Step 2:** Enter the correct username and password, then click "Sign In." Upon successful login, the home screen of the iPROLEPSIS Games app will appear.

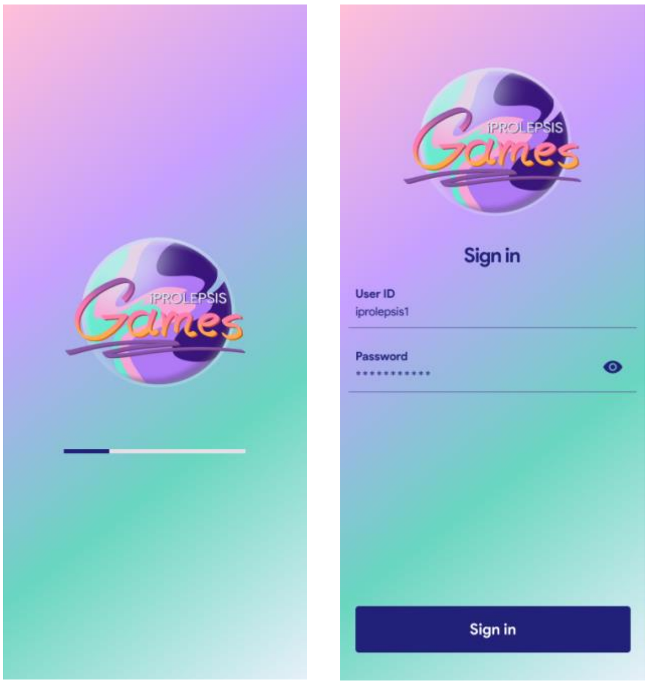



**Figure 22** Snapshot of the Loading screen (left) and Login screen (right).

### 3.2.3 Games Menu navigation

The home screen of the iPROLEPSIS Games application and its functionalities are shown in the figure below (see **Figure 23**). From the home screen, users can access the following features:

[22] This step is planned to be fully functional by M34.
[23] Apple requirements will be provided at a later stage of the project.
[24] Apple requirements will be provided at a later stage of the project.
[25] The loading animation was created using Unity's radial images.

- Access to the Games
- Access to the Calendar (currently in the design phase, not yet implemented)
- Access to the Stats (currently in the design phase, not yet implemented)

After the loading screen, the player is presented with the Main Menu, which includes six buttons to navigate to different game categories and an exit button.

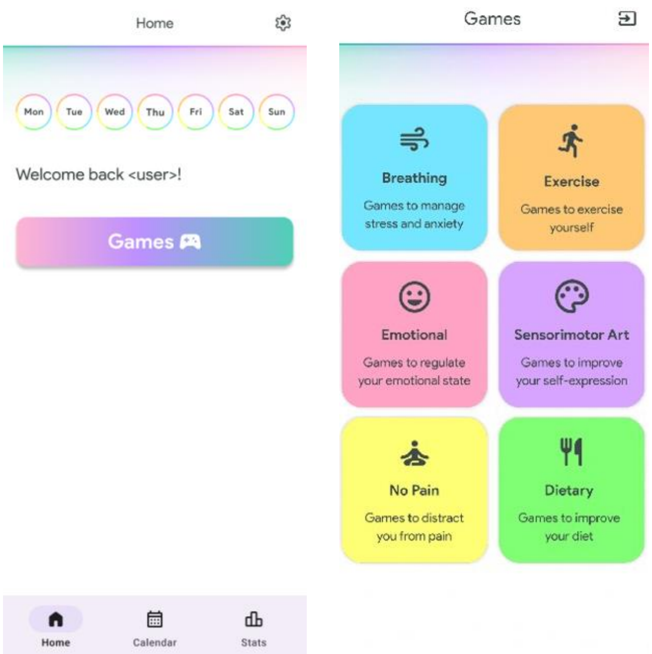



**Figure 23** Snapshot of the Home Screen (left) and Games Main Menu Screen (right).

### 3.2.4 Progress tracking

The iPROLEPSIS Games app was originally structured with games containing 3 to 4 static levels that unlocked sequentially. However, once players completed all levels, new content was limited. To enhance long-term engagement, a dynamic progression system has been designed, converting static levels into a performance-based "path" where each original level is divided into smaller challenges (e.g., reaching a specific score) (see **Figure 24**). This approach, inspired by the Duolingo[26] path framework, offers a longer gameplay experience and a steady sense of progression, allowing players to advance or retreat along the path based on performance. This progression system is currently in the design phase.

### 3.2.5 Healthcare professional's interaction

Development is in progress for an HCP recommendation feature intended to be integrated into the miPROLEPSIS HCP app at a later stage of the project. This feature will enable personalized game and category recommendations tailored to individual needs and symptoms. While specifics of how HCPs will assign games are still being refined, an initial design concept has been developed. Drawing inspiration from Duolingo, the feature will use a circular daily task set, optimized for screen space, where color-coded categories with adjustable transparency indicate task completion. Players can view both the prescription screen and the general game menu, allowing them to follow recommendations while exploring the app freely (see **Figure 25**). This HCP interaction functionality is currently in the design phase and has not yet been implemented.

[26] https://en.duolingo.com/

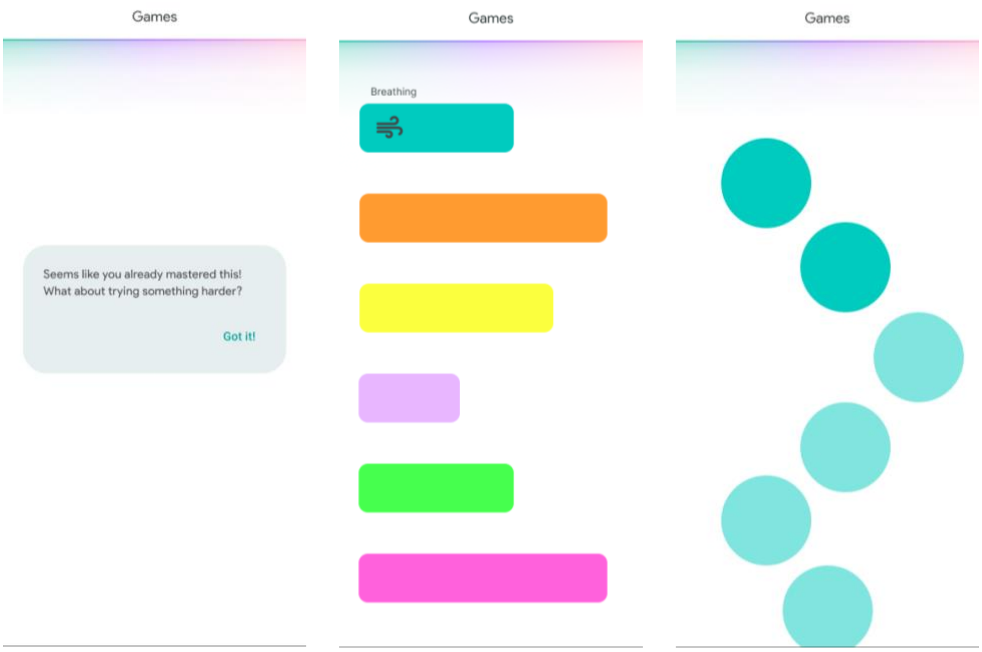



**Figure 24** Snapshot of the level-up pop-up prototype (left), level bar indicators prototype (center), and initial prototype for a new level path (right).

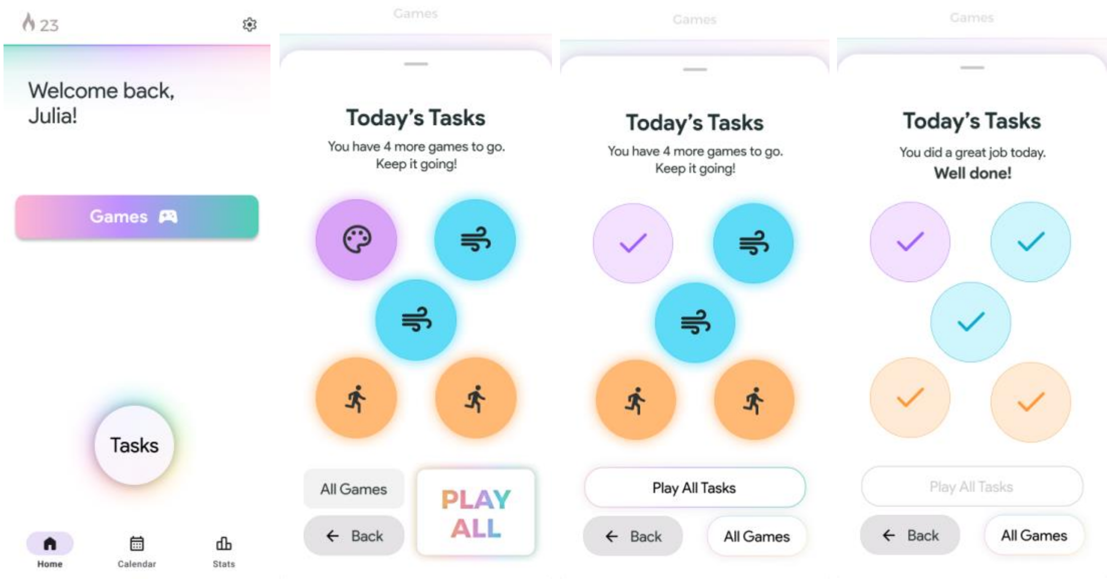



**Figure 25** Snapshot of HCP prescription screen prototypes.

### 3.2.6 Gamification

The gamification elements of the iPROLEPSIS Games app have been conceptualized, focusing on integrating streaks, badges, and community features. Streaks would encourage players to continue playing to maintain their progress, while badges would track accomplishments, fostering engagement and a sense of achievement. Players would have the option to share badges, boosting both involvement and app promotion. All badges would be stored in a profile album for easy access and review (see **Figure 26**). These gamification features are currently in the design phase and have not yet been implemented.

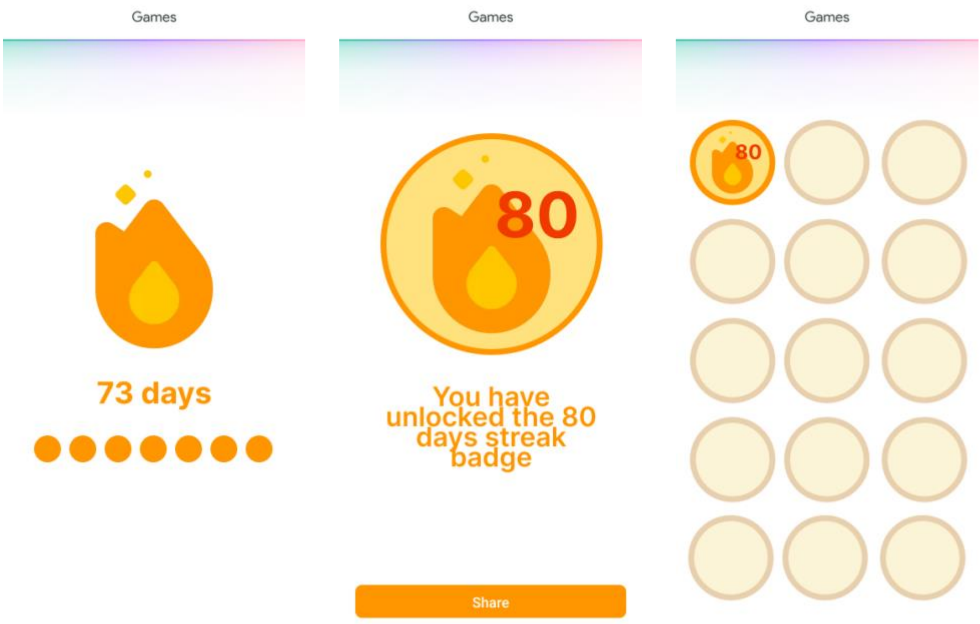



**Figure 26** Snapshot of the streak increase screen prototype (left), badge achievement screen prototype (center), and streak collection screen prototype (right).

### 3.2.7 General Audio

Audio plays a key role in the iPROLEPSIS Games app, with each serious game featuring unique music and sound effects. However, the focus here is on the general audio management system. A universal sound object has been implemented to ensure seamless audio across scenes, addressing challenges like scene unloading that would otherwise disrupt sound continuity. This object manages all background music and sounds, such as transitioning from the main menu to in-game soundtracks. For instance, when moving from the Breathing Games Category Menu to "The Kite" game, the sound transitions smoothly without interruption.

The main menu features music sourced from a free playlist on Itch.io[27], which was customized using AudioMass[28]. A critical, often overlooked sound is the button click, which is handled with its own system to ensure it plays fully before the sound object is destroyed, preventing abrupt cuts. To avoid overlapping sounds when buttons are pressed rapidly, older sounds are halted, ensuring a clean and cohesive audio experience throughout the app.

### 3.2.8 Breathing Games and "More Info" section

As a result of feedback from the co-creation session#3, a "More Info" button was added to each category's menu, providing users with access to clinical and relevant information validating each category. Initially presented as a dense block of text with hyperlinks, the content was reorganized into smaller, topic-based paragraphs for better readability. Icons were added to each section to visually represent the information, making it easier to understand at a glance. The text was also centred for a cleaner look, and a text-to-speech button[29] was included to assist users.

Additionally, short descriptions were added to each game's category button, offering players immediate insight into the game's goals. A three-dot button was introduced for more detailed information on each game. These changes allow players to better understand the differences

[27] https://itch.io/
[28] https://audiomass.co/
[29] The text-to-speech button is currently in the design phase and not yet implemented.

between games and their benefits, while the "More Info" section provides further details on the category as a whole (see **Figure 27**). Although The Kite was developed first, Star Catcher is listed as the first Breathing Game, as it introduces simpler breathing patterns, serving as a beginner-friendly entry to the category and easing the learning curve for The Kite.

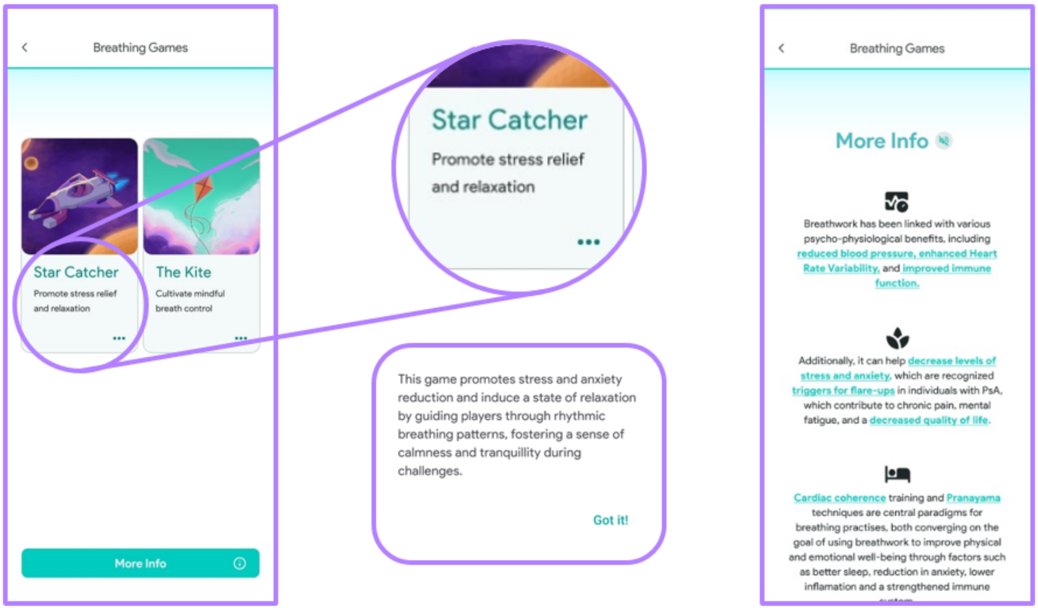



**Figure 27** Snapshot of the Breathing Games category menu and the "More Info" section

### 3.2.8.1 "The Kite" breathing game

"The Kite" is the first breathing game developed for the iPROLEPSIS Games app, aimed at helping players relax and manage stress, with particular benefits for PsA patients who often experience elevated stress levels. Drawing inspiration from Pranayama and cardiac coherence practices[30] the game guides players in following specific breathing patterns that are known to reduce stress.

In the game, players control a paper kite, with its movement directly influenced by their breathing. By maintaining the correct rhythm, the kite glides smoothly, avoiding obstacles. However, if the player's breathing falters, the kite veers off course, risking collision or drifting too high.

#### 3.2.8.1.1 Connecting a wearable

At the beginning of the "The Kite" breathing game we plan to integrate smartwatch connectivity, allowing the game to monitor players' stress levels in real time, both before and after gameplay (see **Figure 28**). This feature is designed to enhance the personalization and effectiveness of the experience by dynamically responding to physiological feedback. Currently, the integration is in the design phase and has not yet been implemented.

[30] Jerath, R., et al. (2006). Physiology of long pranayamic breathing: neural respiratory elements may provide a mechanism that explains how slow deep breathing shifts the autonomic nervous system. Medical hypotheses, 67(3), 566-571.

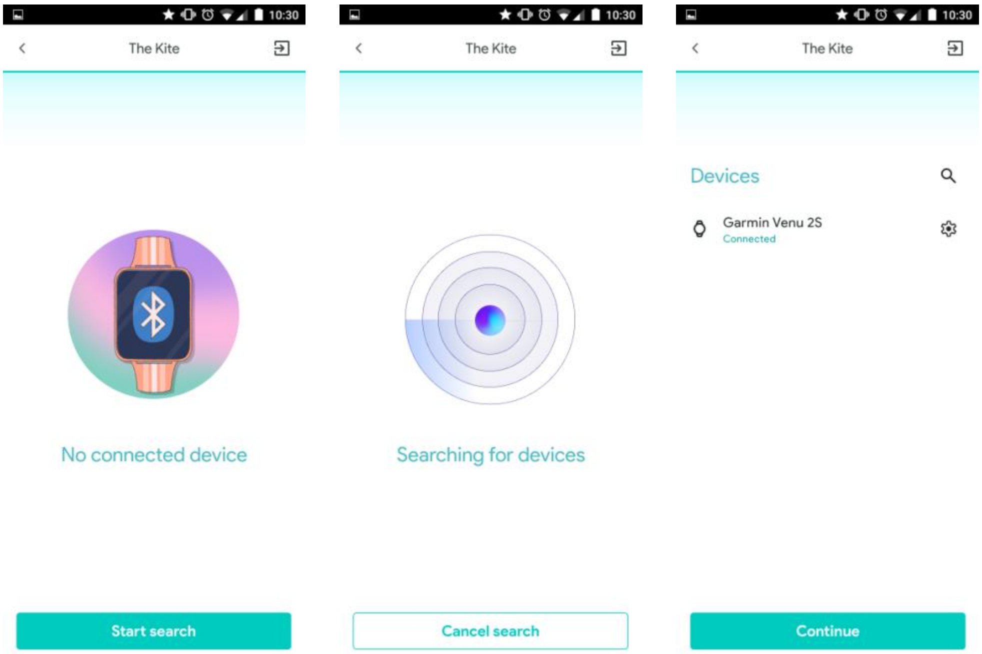



**Figure 28** Snapshot of “The Kite” Breathing Game showcasing smartwatch connectivity integration.

#### 3.2.8.1.2 Menus

The “The Kite” game includes custom-designed menus distinct from the shared menus of the iPROLEPSIS game suite. These menus, grouped for clarity, are depicted in **Figure 29** and serve specific functions within the game.

The **loading screen** features a simple layout with the game title, a loading bar, and a blue-to-white gradient background. Although the loading bar is currently cosmetic, future plans include using this time to establish smartwatch communication (see **Figure 29**-left).

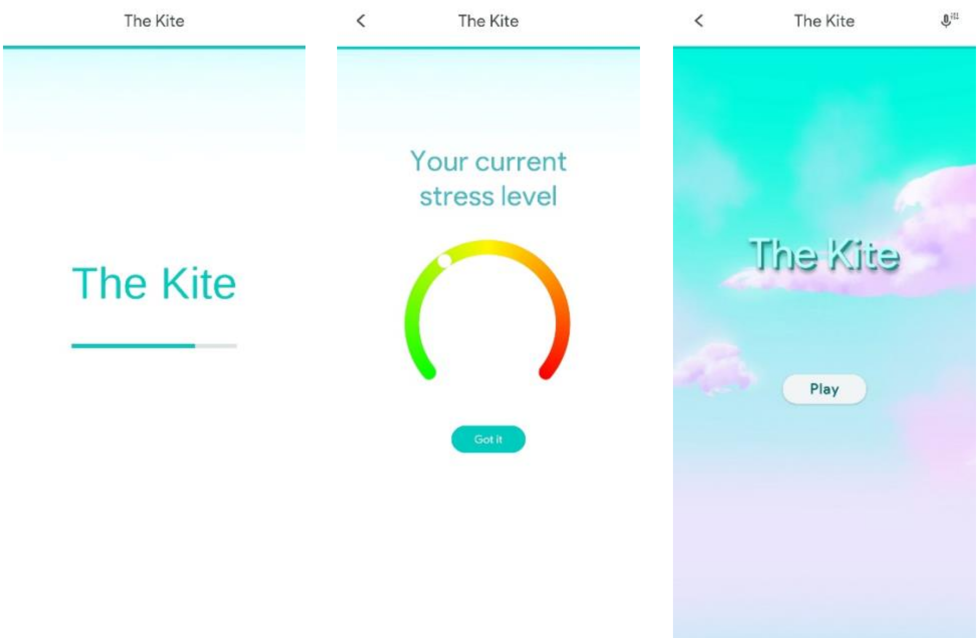



**Figure 29** Snapshot of “The Kite” Breathing Game displaying the loading screen (left), current stress level indicator (center), and the gameplay screen with the play button (right).

The **stress level screen** displays the user's stress level before gameplay, providing a baseline for comparison with post-game readings. This will eventually be connected to a smartwatch to enhance accuracy. The interface includes a gradient scale (green for no stress to red for high stress) with a movable label to indicate the stress level dynamically. This screen is currently in the design phase and has not yet been implemented (see **Figure 29**-center).

The **main menu** consists of top UI elements, navigation buttons, a calibration button located at the top-right corner, and a play button to advance to the next phase. Its calming skybox background contrasts with the white-gradient backgrounds of earlier menus, creating a serene environment (see **Figure 29**-right).

The **end game menu** displays the player's score and a positive performance message upon completion. The score is retrieved from a saved variable, and once displayed, the screen transitions to the final end-game screen, which includes options to either "Play Again" or "Quit". Each menu is thoughtfully designed to align with the game's calming aesthetic and functional goals (see **Figure 30**).

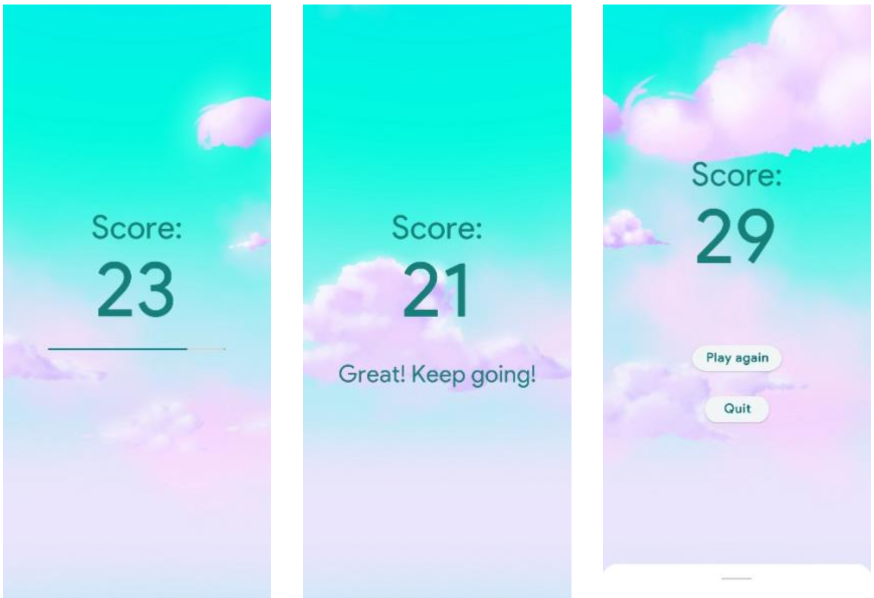



**Figure 30** Snapshot of the end game menu in "The Kite" Breathing Game, showcasing the player's score, performance message, and options to "Play Again" or "Quit."

The **difficulty levels screen**, shown in **Figure 31**, is the final menu before entering the game, allowing players to select their preferred difficulty level. Upon selecting "Play" from the main menu, the player is redirected to this screen. The UI includes background elements, top menu, and several buttons representing four difficulty levels: Beginner, Intermediate, Advanced, and Expert. Initially, only the Beginner level is unlocked, with subsequent levels becoming available after achieving victory at the previous difficulty. Player preferences are saved using Unity Player Preferences.

Once a difficulty level is selected, the "Play" button is enabled. A countdown begins once clicked, transitioning the player into the game. Additionally, the screen includes a "Tutorial" button that takes the player to the practice section.

In addition, the screen features a **warning** to ensure the player completes the tutorial before proceeding. This warning appears only once and will not be shown again once the tutorial is completed or if the player opts to skip it.

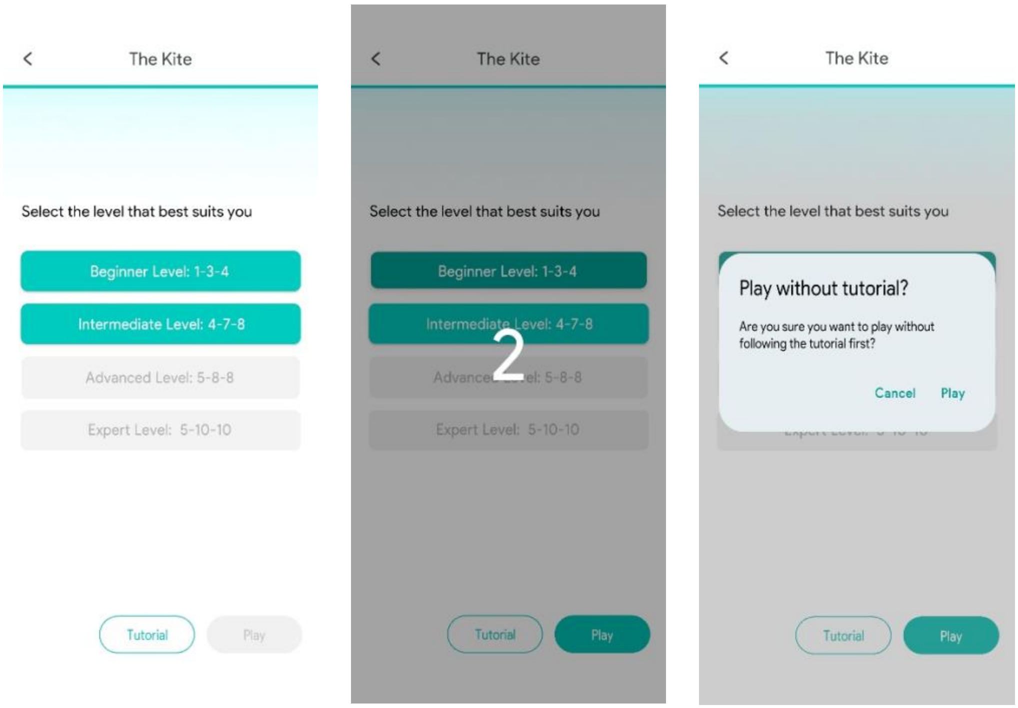
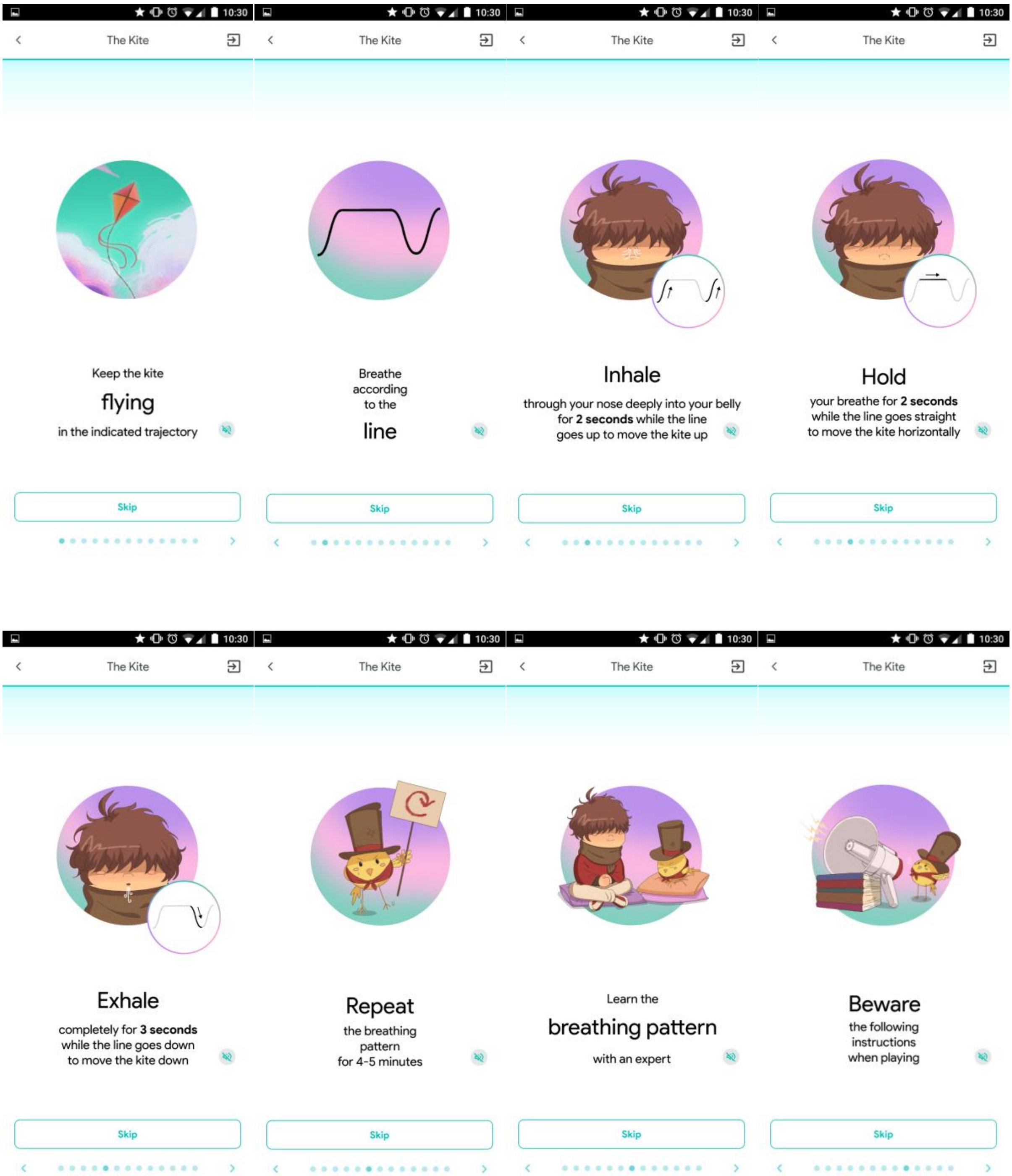



**Figure 31** Snapshot of the difficulty level screen in "The Kite" Breathing Game, showcasing the four difficulty levels (left and center) and the warning regarding tutorial completion (right).

The **Tutorial** phase in “The Kite” Breathing Game, as shown in **Figure 31**, is accessed via a 'Tutorial' button on the difficulty level menu. This phase, critical for the breathing algorithm’s calibration and calm environment requirements, provides essential game instructions but does not explain gameplay in detail—that is covered in the **practice** menu.

The tutorial screen features the standard top and background UI elements, along with new elements like a series of several scrolling panels that describe the game’s movements (see **Figure 32**). The player can navigate through the panels by dragging left or right, with intuitive and fluid transitions. A skip button quickly advances to the last panel, which is then replaced with a practice button. For those preferring not to scroll, arrow buttons facilitate automatic transitions.

Markers at the bottom indicate the current panel, updating as the player moves through the tutorial. A persistent sound button in the bottom right is intended to trigger voice-over instructions, though the audio has not yet been developed. Panels three and five of **Figure 32** include animated GIFs to demonstrate breathing movements (inhale, exhale), created using Unity's video and raw image components.


10:30
The Kite
Keep the kite
flying
in the indicated trajectory
Skip
10:30
The Kite
Breathe
according
to the
line
Skip
10:30
The Kite
Inhale
through your nose deeply into your belly
for **2 seconds** while the line
goes up to move the kite up
Skip
10:30
The Kite
Hold
your breathe for **2 seconds**
while the line goes straight
to move the kite horizontally
Skip
10:30
The Kite
Exhale
completely for **3 seconds**
while the line goes down
to move the kite down
Skip
10:30
The Kite
Repeat
the breathing
pattern
for 4-5 minutes
Skip
10:30
The Kite
Learn the
breathing pattern
with an expert
Skip
10:30
The Kite
Beware
the following
instructions
when playing
Skip

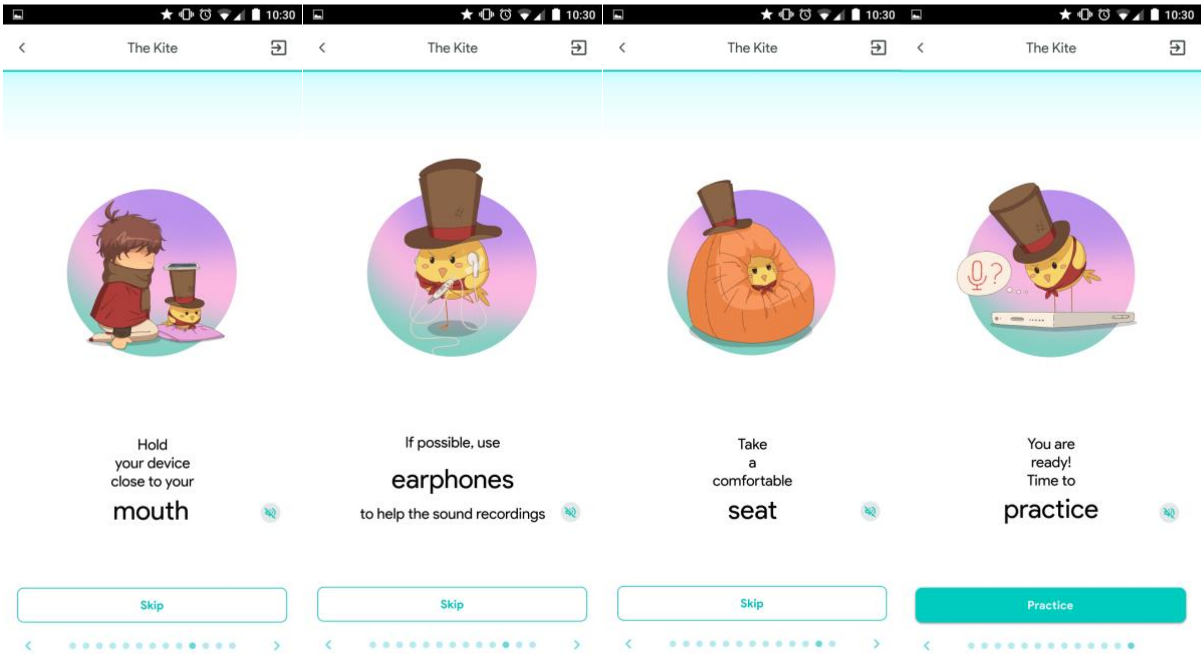



**Figure 32** Snapshot of the tutorial screens in "The Kite" Breathing Game.

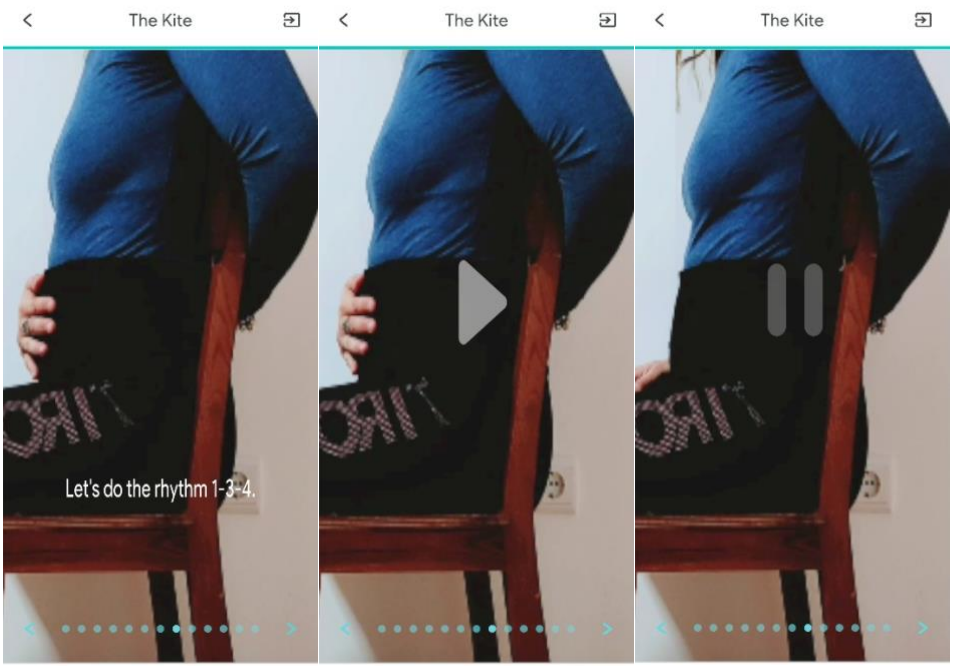



**Figure 33** Snapshot of the tutorial screen in "The Kite" Breathing Game, featuring an expert demonstration of the breathing movements required for gameplay.

**Figure 33** highlights the **video** panel, the missing panel from the tutorial menu. This section features a raw image background and a video player showcasing an expert demonstrating the breathing movements for the game.

A playback management system ensures the video stops if the player navigates away and automatically restarts upon return. Players can pause and resume the video by tapping it.

Background music temporarily disables during video playback to ensure clear audio and resumes after the video ends. Subtitles were added for accessibility, synchronized with the video's duration.

The **End game screen**, shown in **Figure 34**, follows the loading score screen and marks the conclusion of the game. It displays the player's final score along with two primary options: a "Play again" button to replay the game and a "Quit" button to return to the main menu.

Additionally, a draggable submenu at the bottom offers detailed feedback on the player's performance, including their updated stress level (indicating the potential impact of the game, though this feature is not yet implemented) and the count of correct and incorrect breathing cycles. This feature enhances player understanding of their performance, even if they succeeded despite making some errors.

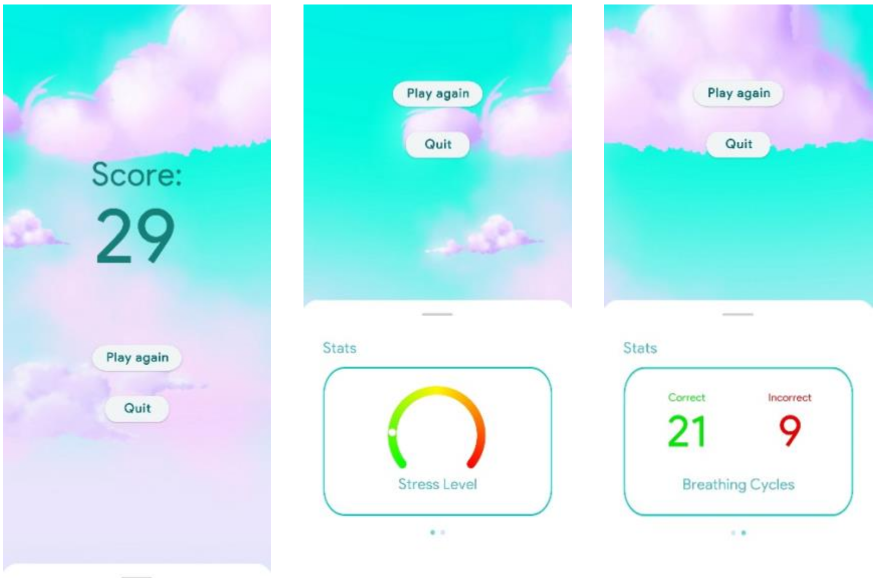



**Figure 34** Snapshot of the final score and player stats screens in "The Kite" Breathing Game.

The development of these menus evolved through iterative feedback from the serious games team, the iPROLEPSIS consortium, patients, and medical/technical experts. The final design aims to deliver a seamless and user-friendly experience.

#### 3.2.8.1.3 Algorithm

In collaboration with the AUTH partner, an algorithm was developed for this serious game to detect inhalation, exhalation, and the associated breathing force. The algorithm requires an initial calibration phase to account for environmental and microphone variations, minimizing errors. During calibration, players follow a breathing pattern to collect data for algorithm optimization, with options to recalibrate or exit if necessary. Successful calibration allows smooth algorithm integration into gameplay (see **Figure 35**).

The algorithm outputs breathing force values, typically ranging between -5 and 5, with negative values indicating exhalation, positive values for inhalation, and 0 for no breath. The system also detects transitions between breathing phases, represented by slopes on a graph. These transitions were leveraged to enhance game functionality.

Testing revealed differences between ideal (red line) and realistic (green line) breathing patterns, highlighting the challenge of distinguishing minor errors from significant ones (see **Figure 36**). Players are advised to use headphones with built-in microphones for accurate performance.

Figures illustrate the calibration scene, algorithm testing, and gameplay elements, providing a comprehensive understanding of its operation and integration into the game.

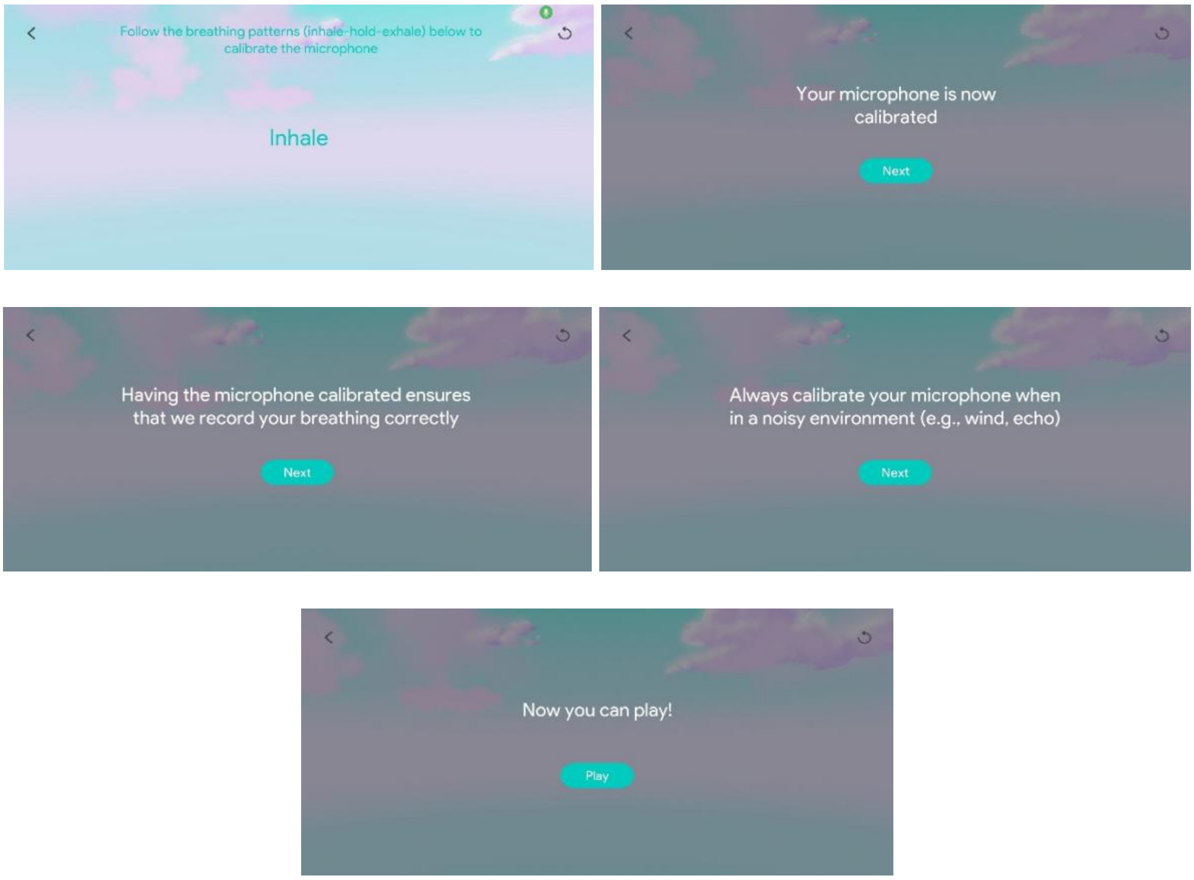



**Figure 35** Snapshot of the calibration scene of the “The Kite” Breathing Game.

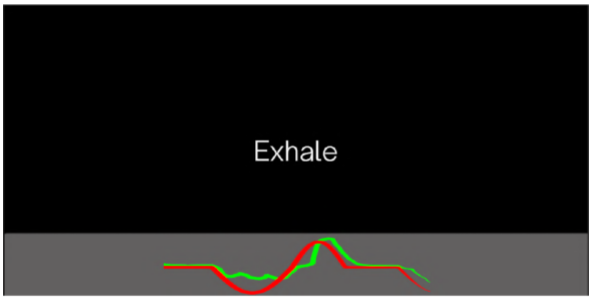



**Figure 36** Snapshot showcasing the similarity of the desired (red) and user’s (green) breathing pattern (here exhale breathing phase) for the algorithm testing phase in “The Kite” Breathing Game.

#### 3.2.8.1.4 Scene

After introducing the menus and algorithms for “The Kite”, the game environment takes center stage. This serious game revolves around a paper kite flying serenely in a forest clearing, with the player controlling its movement through breathing patterns. Key elements of the game include:

1. **The Kite**: A 3D model with flowing motion enhanced by Unity’s cloth system, simulating natural movement. A concave black line represents the kite's string.
2. **The Forest Environment**: Created using free Unity assets and a custom generator to place randomized trees within a torus-shaped region. The ground features a grassy field simulated through Unity’s terrain system.

3. **Obstacles**: Introduced as the game progresses, obstacles include houses and tree groups. These add immersion and challenge.
4. **Dynamic Sky**: A skybox with drifting clouds, giving a realistic sense of motion.
5. **Lighting and Camera**: A directional light illuminates the scene, while a perspective camera tracks the kite.

The gameplay focuses on breathing patterns to control the kite's height along the Y-axis:

- Inhaling raises the kite.
- Holding breath maintains its altitude.
- Exhaling lowers the kite.

The game provides visual aids, including green dots indicating the kite's projected path, and a performance indicator using color-coded feedback (see **Figure 37**). Incorrect breathing leads to error accumulation, destabilizing the kite's movement and increasing collision risks.

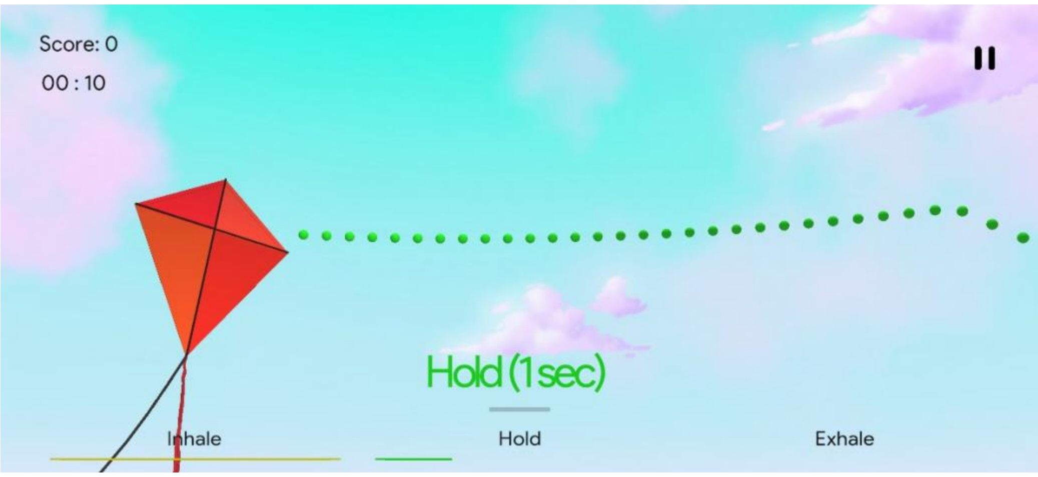



**Figure 37** Snapshot displaying the first 10 seconds of gameplay in "The Kite" Breathing Game.

Players can lose by letting the kite fly away, colliding with obstacles, or reaching a critical error threshold. Loss events are represented through animations or particle effects, like a smoke trail. After completing four minutes of gameplay, winning occurs, concluding with positive feedback.

Overall, The Kite integrates breathing mechanics with adaptive visual and auditory feedback, aligning with its stress-relief objective. This simple yet engaging design encourages proper breathing and maintains player immersion.

#### 3.2.8.1.5 Game

The Kite centers around a kite controlled by the player's breathing patterns (see **Figure 38**). The kite moves in a circular path, with the player controlling its altitude through inhaling, holding, and exhaling according to a specific breathing cycle. The difficulty adjusts the cycle's duration for each phase. The game starts with a practice cycle, then progresses with the player maintaining the correct rhythm to keep the kite stable.

The game interface includes a score tracker, phase timer, and a pause menu, with performance indicators in the form of coloured bars (green, yellow, red) based on the accuracy of the player's breathing pattern. A set of green dots predicts the kite's path, and the game tracks errors when the player's breathing deviates from the recommended pattern. Increased error causes the kite's movement to become erratic, making it more prone to collisions with obstacles (see **Figure 39**).

The player loses if the error threshold is reached, causing the kite to either crash or fly away. The collision is simulated with a particle system, and a sound effect is played. Players have the option to pause and resume the game at any time, ensuring flexibility and uninterrupted progress (see **Figure 40**). The game ends with a win after four minutes if the player successfully completes the cycle.

Overall, The Kite integrates breathing exercises with error tracking and dynamic feedback, aiming to help players regulate their breathing while providing a fun and challenging experience.


**Figure 38** Snapshot illustrating the player’s breathing patterns (inhale, hold, exhale) in "The Kite" Breathing Game.

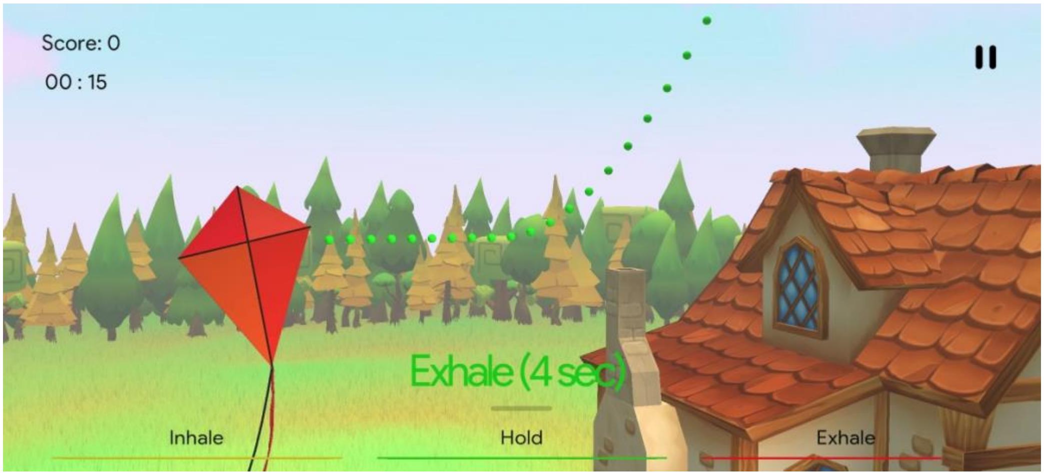



**Figure 39** Snapshot showcasing potential obstacles (e.g., house) in "The Kite" Breathing Game.

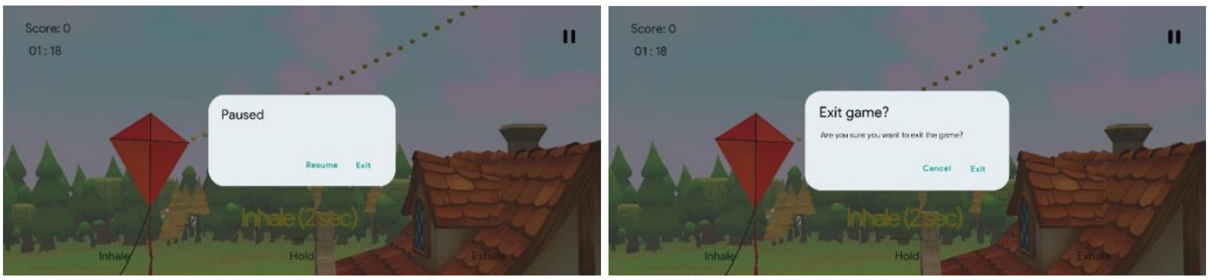



**Figure 40** Snapshot displaying the pause system in "The Kite" Breathing Game.

#### 3.2.8.1.6 Game orientation & game to menu transition

The game design employs both vertical and horizontal orientations to enhance user experience. The menus are displayed vertically, while the game itself is played in a horizontal layout. This choice maximizes screen space and aligns with the game's movement, which progresses from left to right. Additionally, it distinguishes this game from another game, Star Catcher, which uses a vertical orientation.

To smooth the transition between the vertical menu and horizontal gameplay, a fade-out effect with a countdown is used before switching scenes, followed by a fade-in effect for the horizontal scene. This helps address potential issues with screen distortion on lower-frame-rate phones when switching orientations, ensuring the transition is visually seamless.

The orientation changes are achieved easily with Unity's Screen Orientation feature[31], supported by a custom script that toggles between vertical and horizontal modes. This integration allows for a smooth transition and gameplay experience across different device orientations.

#### 3.2.8.1.7 Difficulty levels

Progression and increasing challenges are vital to game design, as emphasized by Sigailov[32]. To incorporate this into the iPROLEPSIS Games, difficulty levels have been created. Each game has a unique approach to difficulty, where higher levels increase the impact of the 'Error' metric. At higher difficulties, deviations from the expected output are more pronounced, affecting both the 'Error' and quality metrics.

Breathing patterns also adapt to difficulty levels. Instead of the standard pattern (inhale for 1 second, hold for 3, exhale for 4), more challenging patterns are introduced:

- Beginner: Inhale for 1 second, hold 3 seconds, exhale 4 seconds.
- Intermediate: Inhale 4 seconds, hold 7 seconds, exhale 8 seconds.
- Advanced: Inhale 5 seconds, hold 8 seconds, exhale 8 seconds.
- Expert: Inhale 5 seconds, hold 10 seconds, exhale 10 seconds.

Additionally, higher difficulty levels increase the likelihood of obstacles, enhancing the challenge. Unity's player preferences feature stores the selected difficulty level, which is then read before the game loads to implement the corresponding difficulty adjustments.

#### 3.2.8.1.8 Audio

The audio design for this game includes various sound elements to enhance the player's experience. For the wind sound, a free asset was edited using Audiomass[33] to add fade-ins and fade-outs while reducing unwanted noise, and it was set to loop in the game. Bird sounds were also edited and combined with the wind to create a serene environment.

The crash sound for when the kite hits was sourced as is, without editing, as it was already suitable. Both the winning and losing sounds were edited with fade-ins, fade-outs, and noise reduction. A ticking sound was added for phase changes to help players synchronize with breathing phases, requiring no editing.

Distinct sounds were used for the game's conclusion: a sad tone for losing and a cheerful sound for winning, both edited minimally with Audiomass.

[31] https://docs.unity3d.com/ScriptReference/Screen-orientation.html
[32] Sigailov-Lanfranchi, J. (2019). Impact of Different Levels of Difficulty on Immersion in Video Games. In AICS (pp. 248-259).
[33] https://audiomass.co/

The main soundtrack, sourced from external assets, was cut using Audiomass to create a relaxing audio loop that plays across all menus and within the game. Combined with the environmental sounds, this creates a calm and gentle atmosphere throughout The Kite.

#### 3.2.8.1.9 Data collected during gameplay

The primary objective of this serious game is to alleviate stress for the player, with the data collected serving as a valuable tool for both players and medical professionals to assess progress and outcomes.

Throughout gameplay, the game captures various data points, which are then sent to a React Native app and subsequently stored in DMS. At present, the game tracks basic metrics: the number of correct and incorrect cycles (integer values), the player's score (integer value), and their stress levels before and after playing (float values)[34].

Although the current data collection is minimal, there are plans to enhance it in the future. By integrating user feedback and refining the process, we aim to improve the depth and scope of the data gathered, ensuring it becomes more comprehensive and meaningful over time.

#### 3.2.8.1.10 Practice scene

The practice scene (see **Figure 41**) was added to provide players with a controlled environment to familiarize themselves with the game mechanics. Recognizing that the tutorial alone might not be sufficient, the practice scene allows players to test the game at their own pace before proceeding to the main gameplay.

This scene mirrors the game environment but includes instructional panels that guide the player through various aspects of the game. The panels are managed by a game manager, which advances to the next step once the player completes specific tasks or clicks a button. The tasks focus on different phases of a breathing cycle, helping players build their understanding and skills.

To accommodate players who may be unfamiliar with the game and allow for algorithm calibration errors, a more flexible version of the algorithm is used in the practice scene. This version focuses on the slopes of the algorithm's data, rather than its accuracy to the ideal pattern, allowing for errors. Overall, the practice scene provides a supportive environment where players can familiarize themselves with the game mechanics before progressing to the main game.


[34] The measurement of stress levels before and after gameplay has yet to be implemented.


**Figure 41** Snapshot of the Practice Scene in "The Kite" Breathing Game.

### 3.2.8.2 "Star Catcher" breathing game

The Star Catcher breathing game, the second game in this category, aims to further promote relaxation and stress reduction, similar to The Kite. Designed for patients with PsA, who often experience elevated stress levels, Star Catcher focuses on reducing stress through breathing patterns based on Pranayama and cardiac coherence techniques[35], known to alleviate stress.

Building on the core mechanics of The Kite, Star Catcher introduces a new scenario where the player guides a spaceship through the universe, collecting stars while managing the spaceship's fuel. Despite these added features, the primary focus remains on guiding the player through calming breathing exercises.

Future updates may include smartwatch integration to monitor and respond to the player's biosignals, further enhancing the game's ability to promote relaxation.

#### 3.2.8.2.1 Connecting a wearable

Similar to The Kite, the "Star Catcher" breathing game plans to integrate smartwatch connectivity at the start, enabling the game to monitor players' stress levels in real time, both before and after gameplay (see **Figure 42**). Currently, the integration is in the design phase and has not yet been implemented.

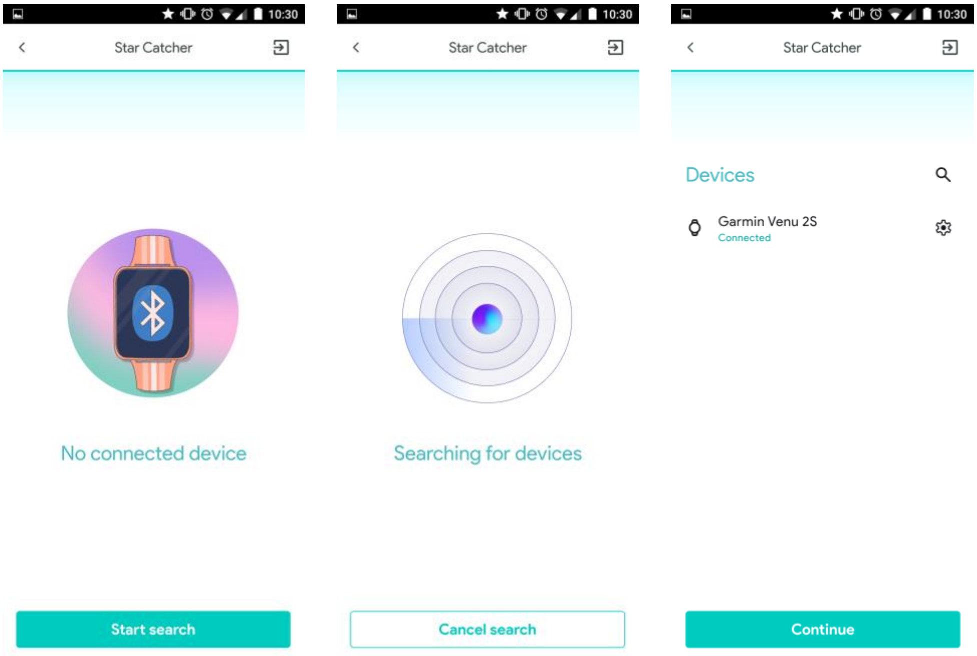



**Figure 42** Snapshot of "Star Catcher" Breathing Game showcasing smartwatch connectivity integration.

#### 3.2.8.2.2 Menus

The Kite breathing game set the standard for shared menus, which is consistently applied across all games, including Star Catcher. The menus in Star Catcher closely resemble those in The Kite, featuring the same color scheme and key breathing-related scenes, such as the calibration scene. As with The Kite, the first group of Star Catcher menus follows the same design, with only minor changes in the name and the background skybox, now reflecting the outer space theme of Star Catcher (see **Figure 43**).

[35] Jerath, R., Edry, J. W., Barnes, V. A., & Jerath, V. (2006). Physiology of long pranayamic breathing: neural respiratory elements may provide a mechanism that explains how slow deep breathing shifts the autonomic nervous system. *Medical hypotheses*, *67*(3), 566-571.

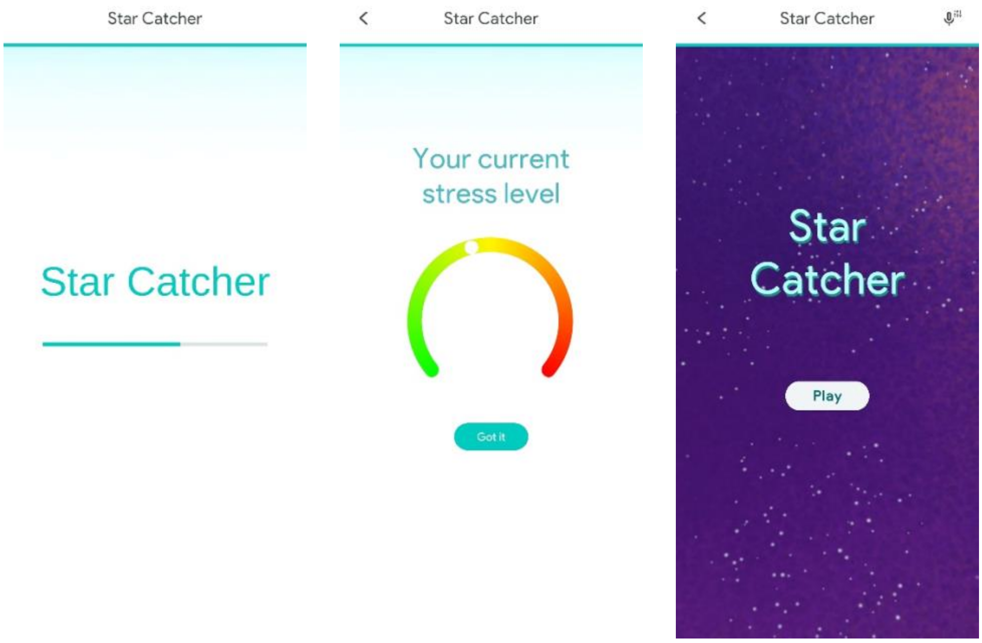



**Figure 43** Snapshot of “Star Catcher” Breathing Game displaying the loading screen (left), current stress level indicator (center), and the gameplay screen with the play button (right).

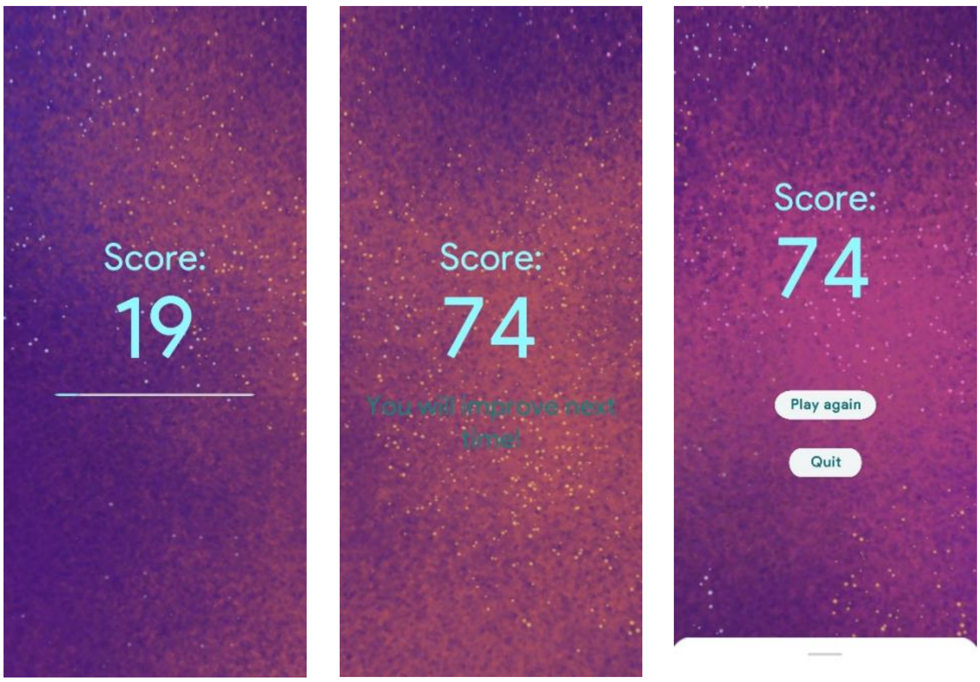



**Figure 44** Snapshot of the end game menu in "Star Catcher" Breathing Game, showcasing the player's score, performance message, and options to "Play Again" or "Quit."

**End game Menus** maintain the same design approach as The Kite game, with the only variation being the updated skybox (see **Figure 44**). **Difficulty level menus** use the same structure with minor adjustments, while transitions and sub-menus from The Kite are seamlessly reused (see **Figure 45**). The **Tutorial Menu** also remains similar, modified to fit the new game context and breathing patterns (see **Figure 46**). Tutorial videos preserve their original features but are adjusted for Star Catcher.

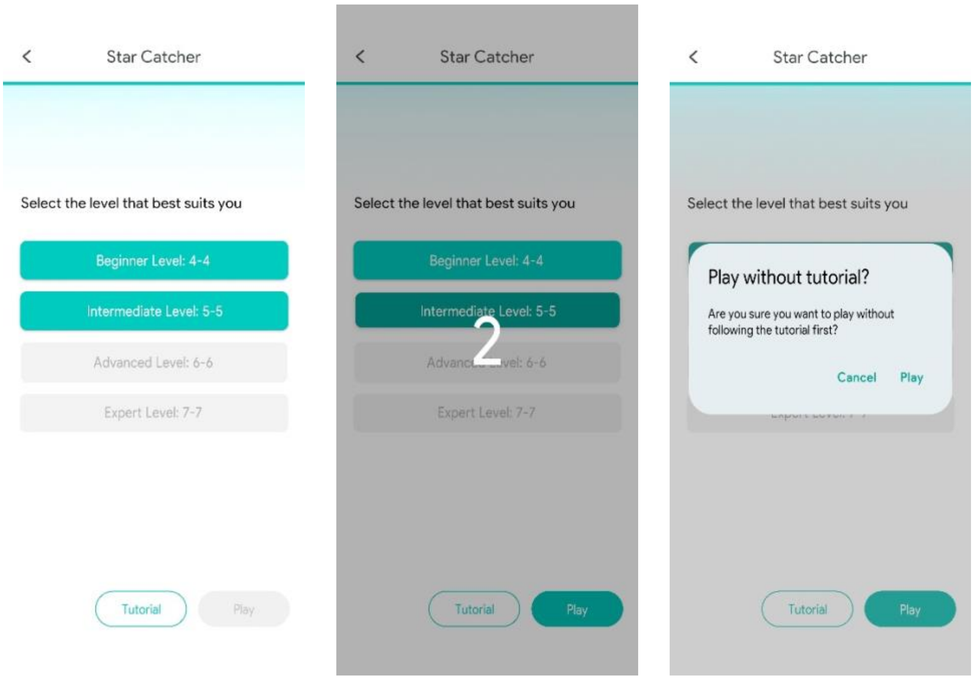
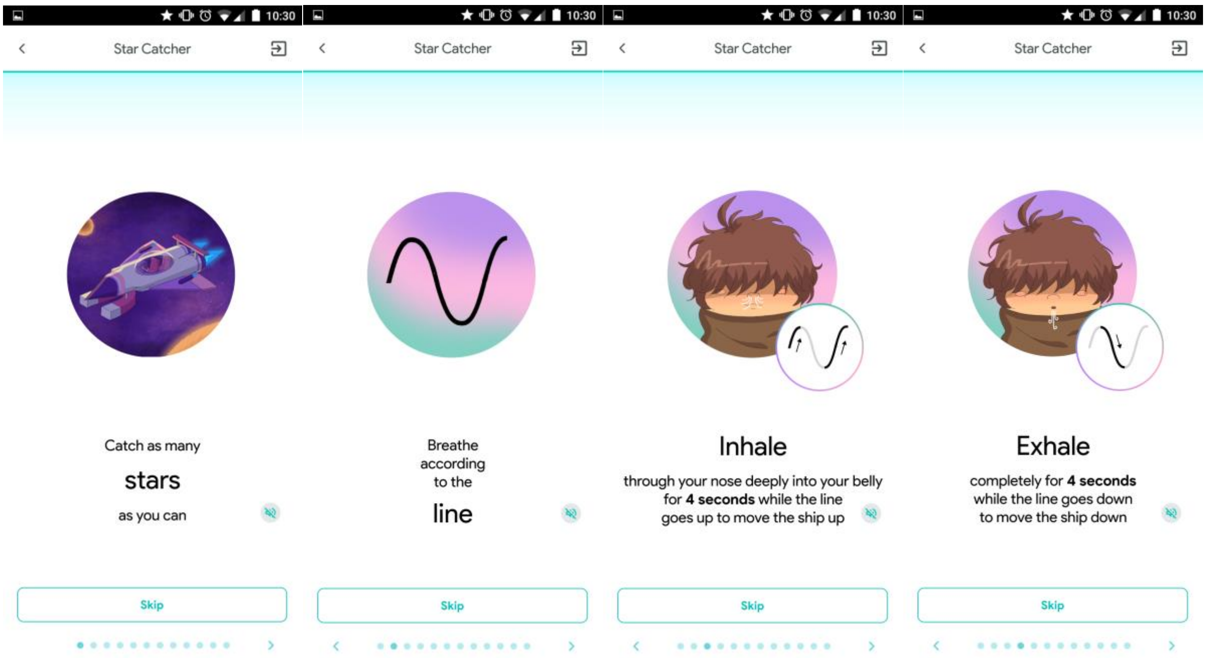



**Figure 45** Snapshot of the difficulty level screen in "Star Catcher" Breathing Game, showcasing the four difficulty levels (left and center) and the warning regarding tutorial completion (right).



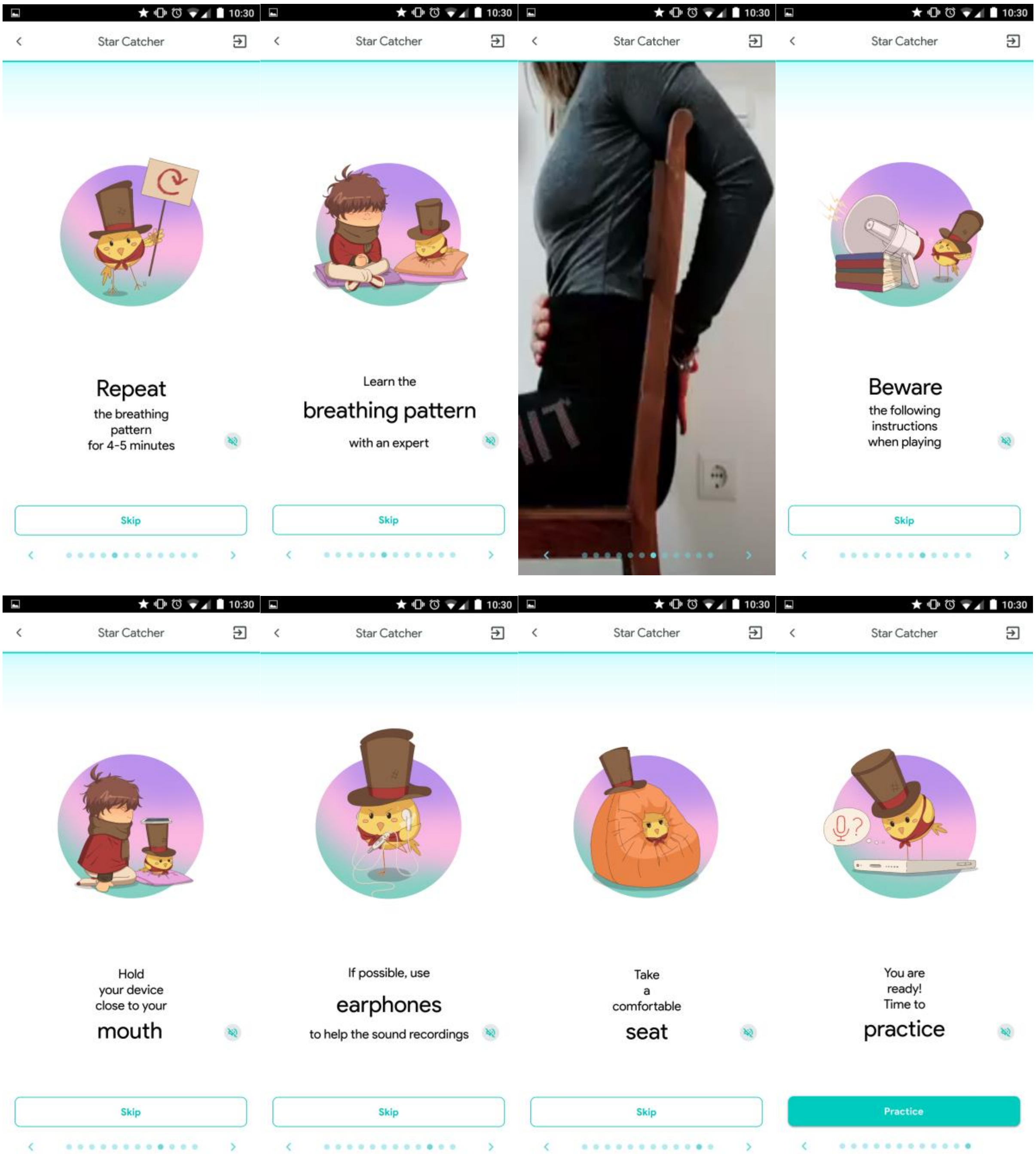



**Figure 46** Snapshot of the tutorial screens in "Star Catcher" Breathing Game.

Similar to The Kite game, the End Game screen (see **Figure 47**) concludes the game by displaying the final score alongside options to "Play again" or "Quit" to the main menu. A draggable submenu at the bottom provides detailed performance feedback, including stress level (feature pending implementation) and the count of correct and incorrect breathing cycles, enhancing player insights.

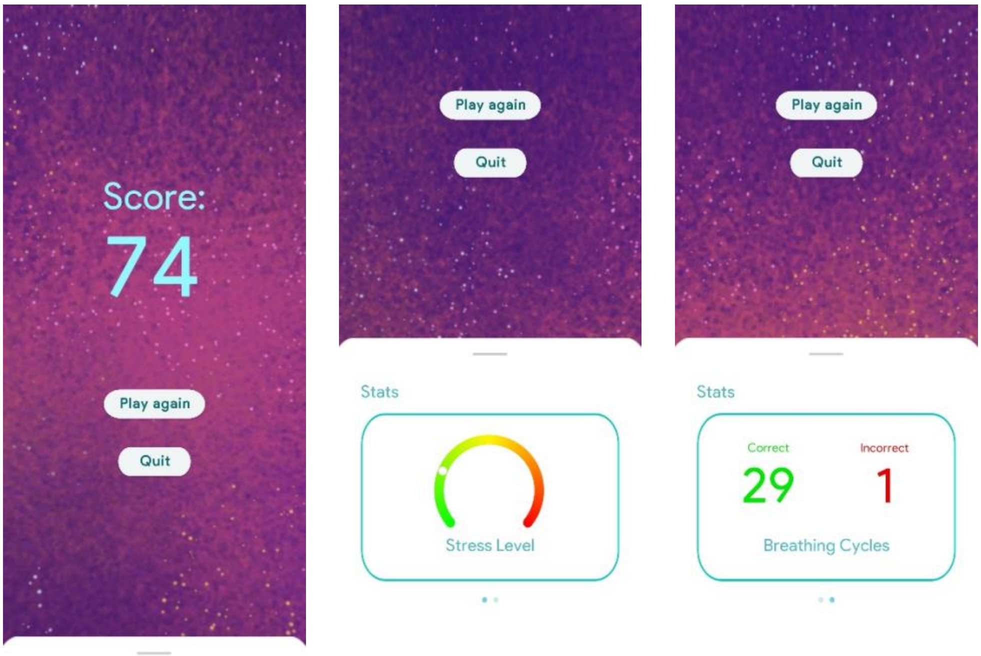
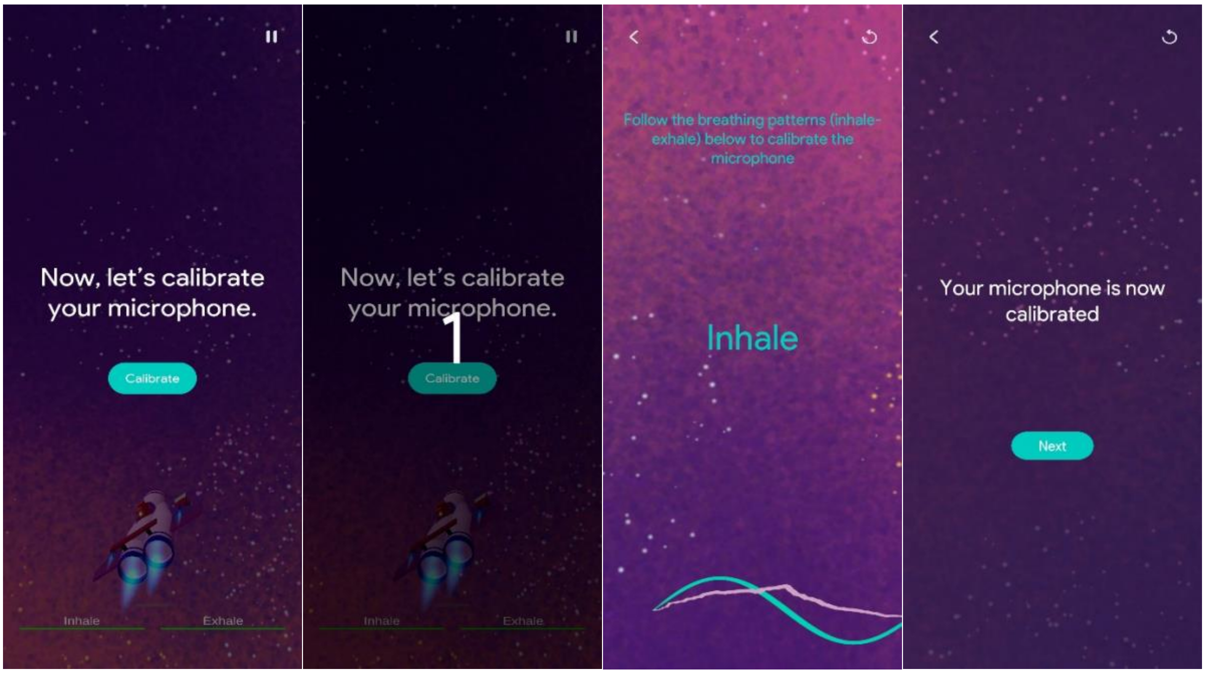



**Figure 47** Snapshot of the final score and player stats screens in "Star Catcher" Breathing Game.

### 3.2.8.2.3 Algorithm

As previously mentioned, both breathing games employ the same algorithm, detailed further in Section 3.2.8.1.3 Algorithm. The algorithm functions similarly in both games, requiring a calibration phase and transmitting identical data types. The primary distinction between the algorithms used in The Kite and Star Catcher lies in their breathing patterns. In Star Catcher, the patterns exclude a holding phase, consisting solely of inhale and exhale phases with varying durations for each (see **Figure 48**).



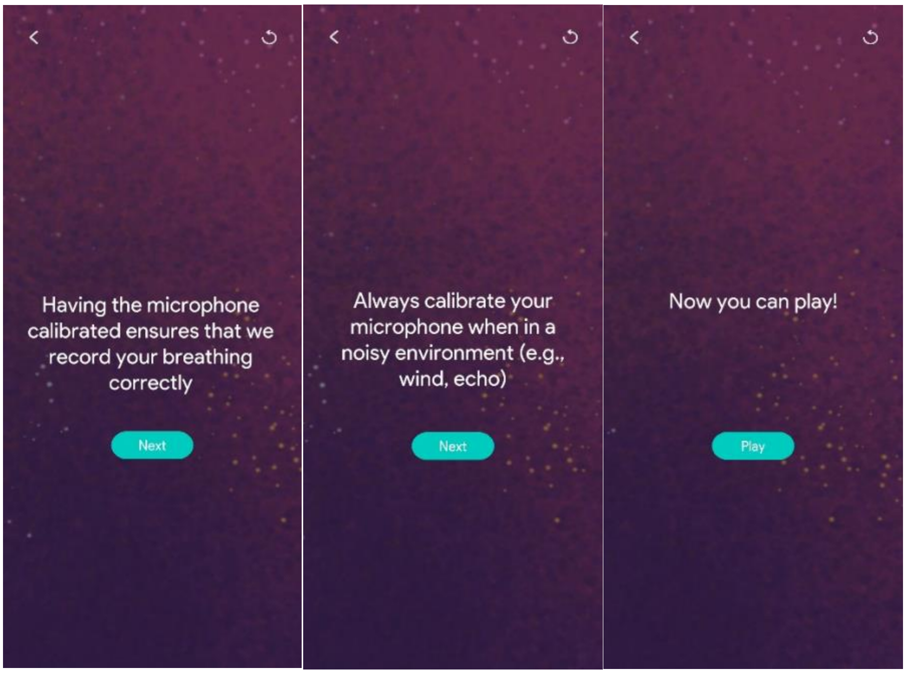



**Figure 48** Snapshot of the calibration scene of the "Star Catcher" Breathing Game.

### 3.2.8.2.4 Scene

Star Catcher shares many gameplay mechanics and objectives with The Kite, but features a completely new environment set in outer space. Instead of controlling a kite, players now pilot a starship surrounded by celestial bodies such as planets, black holes, and asteroids (see **Figure 49**).

The celestial objects in the game are categorized into four main types: a black hole, a planet with a moon colliding with it, a planet with rings, and a planet with visible clouds. These objects are semi-randomly generated and placed in the game world to enhance the visual experience without interfering with the ship's movement.

The game's primary objective is to collect stars represented in a cartoonish style to match the overall aesthetic. These stars are distributed along the predicted path of the spaceship, moving in sync with the player's breathing patterns—diagonal left during inhalation and diagonal right during exhalation. The star placement is automatically adjusted based on the difficulty level.

At the end of the game, if the player successfully completes it, they encounter a special celestial object, marking the ultimate goal. The game also features a skybox that fills the visual space, moving slowly to reflect the vastness of space, similar to The Kite, but at a more realistic pace.

The starship includes particle effects for the engine, created using Unity's particle system. Star Catcher's camera and lighting settings are the same as in The Kite, ensuring consistency across the games.

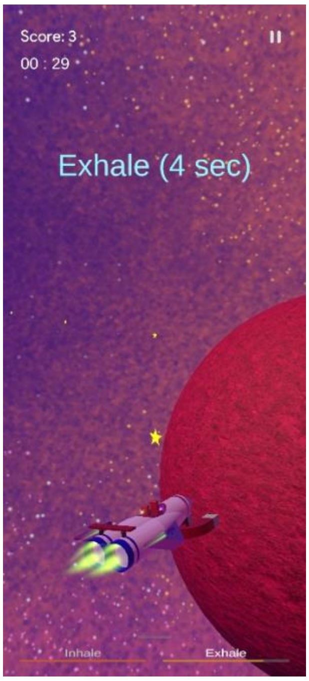



**Figure 49** Snapshot showing the first few seconds of gameplay in the "Star Catcher" Breathing Game.

### 3.2.8.2.5 Game

Star Catcher is a vertical breathing game designed to promote relaxation by utilizing structured inhale-exhale patterns. The interface includes a score and timer in the top left corner, a pause button in the top right, and bottom menus that track player performance during each phase, mirroring features from The Kite (see **Figure 50**).

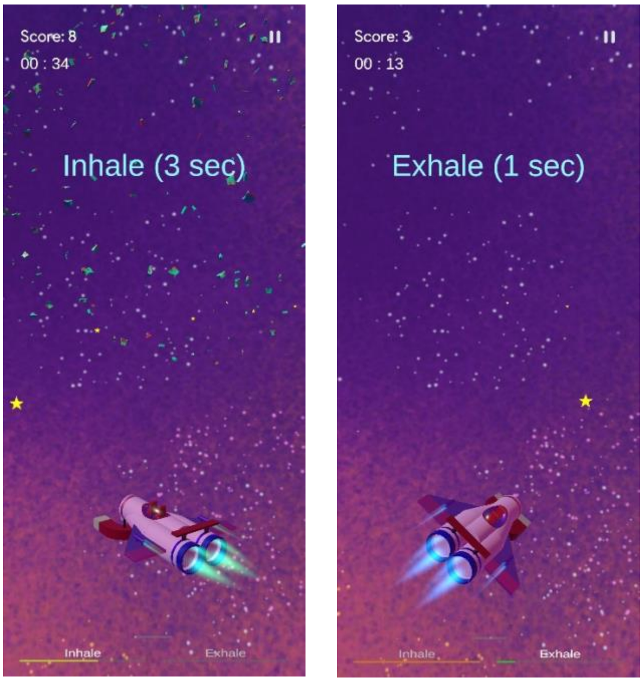



**Figure 50** Snapshot illustrating the player's breathing patterns (inhale, exhale) in "Star Catcher" Breathing Game.

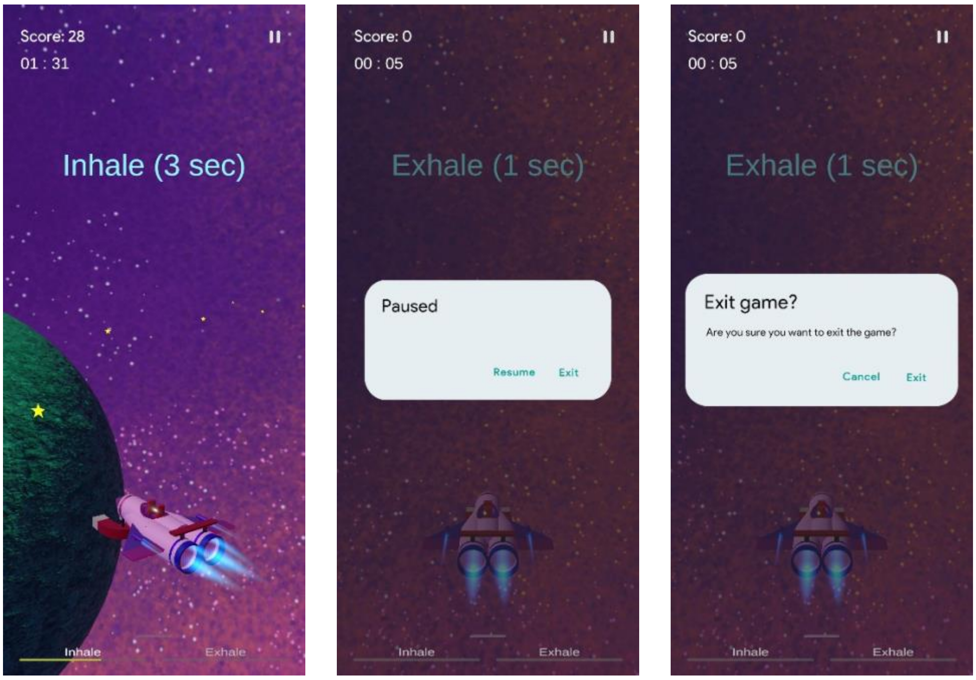



**Figure 51** Snapshot displaying the pause system in "Star Catcher" Breathing Game.

The game starts with a non-scoring "dummy phase," allowing players to familiarize themselves with the rhythm. Gameplay involves guiding a spaceship along an optimal path by following the breathing pattern. Inhaling moves the ship left, and exhaling moves it right. Unlike traditional controls, players influence the ship's trajectory indirectly, reducing potential stress and encouraging steady breathing. Stars, located along the optimal path, serve as both a scoring mechanism and fuel for the ship. Deviating from the breathing pattern causes the ship to veer off course, missing stars and risking fuel depletion, which could result in losing the game. Fuel depletion is visually represented by fading intensity and colour. Similar to the Kite game, players can pause and resume at any time (see **Figure 51**).

Successful gameplay over four minutes leads to victory and a final cosmic destination (see **Figure 52**). The game introduces new mechanics, such as spaceship movement, star generation, and improved code structure, while retaining foundational elements from The Kite. Through iterative development and testing, Star Catcher has been refined to offer a relaxing experience designed to reduce stress, making it a valuable tool for PsA patients.


**Figure 52** Snapshot showcasing the victory screen and the final cosmic destination in the "Star Catcher" Breathing Game.

#### 3.2.8.2.6 Game orientation & game to menu transition

In contrast to The Kite, Star Catcher is played in a vertical orientation. This design choice not only creates more space for forward movement within the game but also provides a fresh perspective, helping distinguish this game from the others. The transitions, such as fade-ins and fade-outs between the game, calibration, and menu scenes, are preserved. These smooth transitions enhance the overall flow of the game, ensuring a seamless experience for players while maintaining a consistent and familiar feature across both games.

#### 3.2.8.2.7 Difficulty levels

Similar to The Kite, Star Catcher also includes difficulty levels to promote progression and increase the challenge for the player. In this game, the "Error" metric is adjusted so that at higher difficulties, the spaceship becomes more prone to drifting off course. This means that any deviations between the player's breathing and the target pattern will have a more significant negative impact on the game.

A new difficulty element in Star Catcher is the fuel system. The spaceship must collect stars to maintain its fuel. If the player fails to gather enough stars, the fuel will gradually deplete. The rate at which fuel runs out is influenced by the selected difficulty, with higher difficulties causing fuel to deplete more quickly. In addition to these changes, the breathing patterns themselves evolve across difficulty levels, as follows:

- Beginner: Inhale for 4 seconds, exhale for 4 seconds.
- Intermediate: Inhale for 5 seconds, exhale for 5 seconds.
- Advanced: Inhale for 6 seconds, exhale for 6 seconds.
- Expert: Inhale for 7 seconds, exhale for 7 seconds.

As with The Kite, Unity's player preferences are used to store the difficulty level selected by the player. This value is read before loading the game, ensuring the appropriate changes are made.

#### 3.2.8.2.8 Audio

Sound design played an important role in enhancing the overall experience of Star Catcher. To promote smoothness and relaxation, new sounds were specifically selected and edited for the game using Audiomass.

The main soundtrack, sourced from a free asset on Itch.io, is a soothing and relaxing piece used across all menus. The original track was shortened and refined with fade-in and fade-out effects for a seamless listening experience. Within the game, a custom sound effect was created for the spaceship's engines. The engine sound, carefully selected and edited, dynamically adjusts its volume based on the spaceship's fuel level, adding a responsive and immersive audio element.

The game's conclusion sounds were also customized. While the positive sound remained unchanged from The Kite, the losing sound was updated to include a power shutdown effect, aligning with the context of the spaceship losing fuel and drifting in space. Other audio cues, such as the ticking sound for phase changes and button sounds, were carried over without modification.

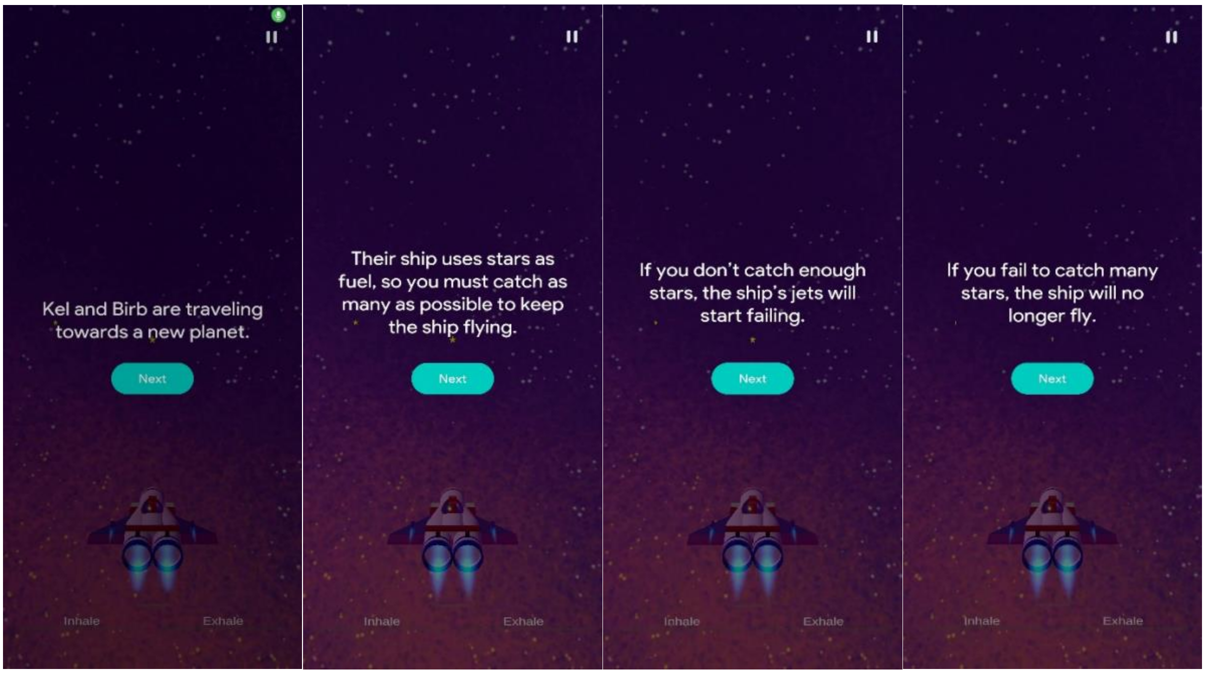
#### 3.2.8.2.9 Data collected during gameplay

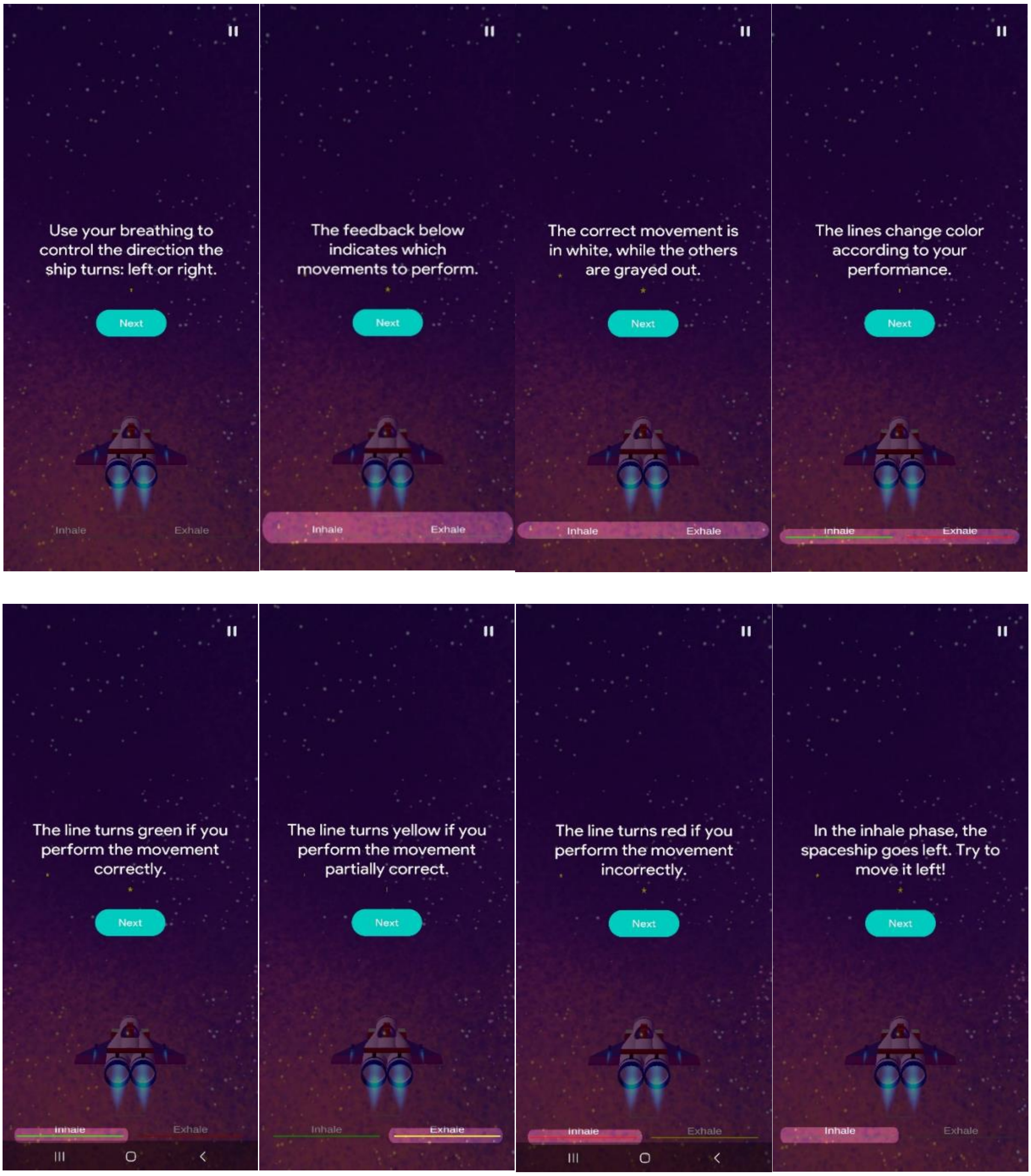
Star Catcher uses the same data collection methods as the previous game. For details, see Section 3.2.8.1.10 Practice scene.

#### 3.2.8.2.10 Practice scene

Like The Kite, Star Catcher includes a practice scene—a controlled environment where players can familiarize themselves with the game mechanics before entering the main gameplay. **Figure 53** illustrates the practice screen.

In line with Star Catcher's vertical orientation, the practice scene is a vertically adapted version of The Kite's practice scene. It consists of a series of panels navigable via buttons or triggered by completing specific activities. These activities include following the expected breathing pattern, which is assessed using a more flexible version of the algorithm.




Use your breathing to control the direction the ship turns: left or right.
Next
Inhale
Exhale
The feedback below indicates which movements to perform.
Next
Inhale
Exhale
The correct movement is in white, while the others are grayed out.
Next
Inhale
Exhale
The lines change color according to your performance.
Next
Inhale
Exhale
The line turns green if you perform the movement correctly.
Next
Inhale
Exhale
The line turns yellow if you perform the movement partially correct.
Next
Inhale
Exhale
The line turns red if you perform the movement incorrectly.
Next
Inhale
Exhale
In the inhale phase, the spaceship goes left. Try to move it left!
Next
Inhale
Exhale

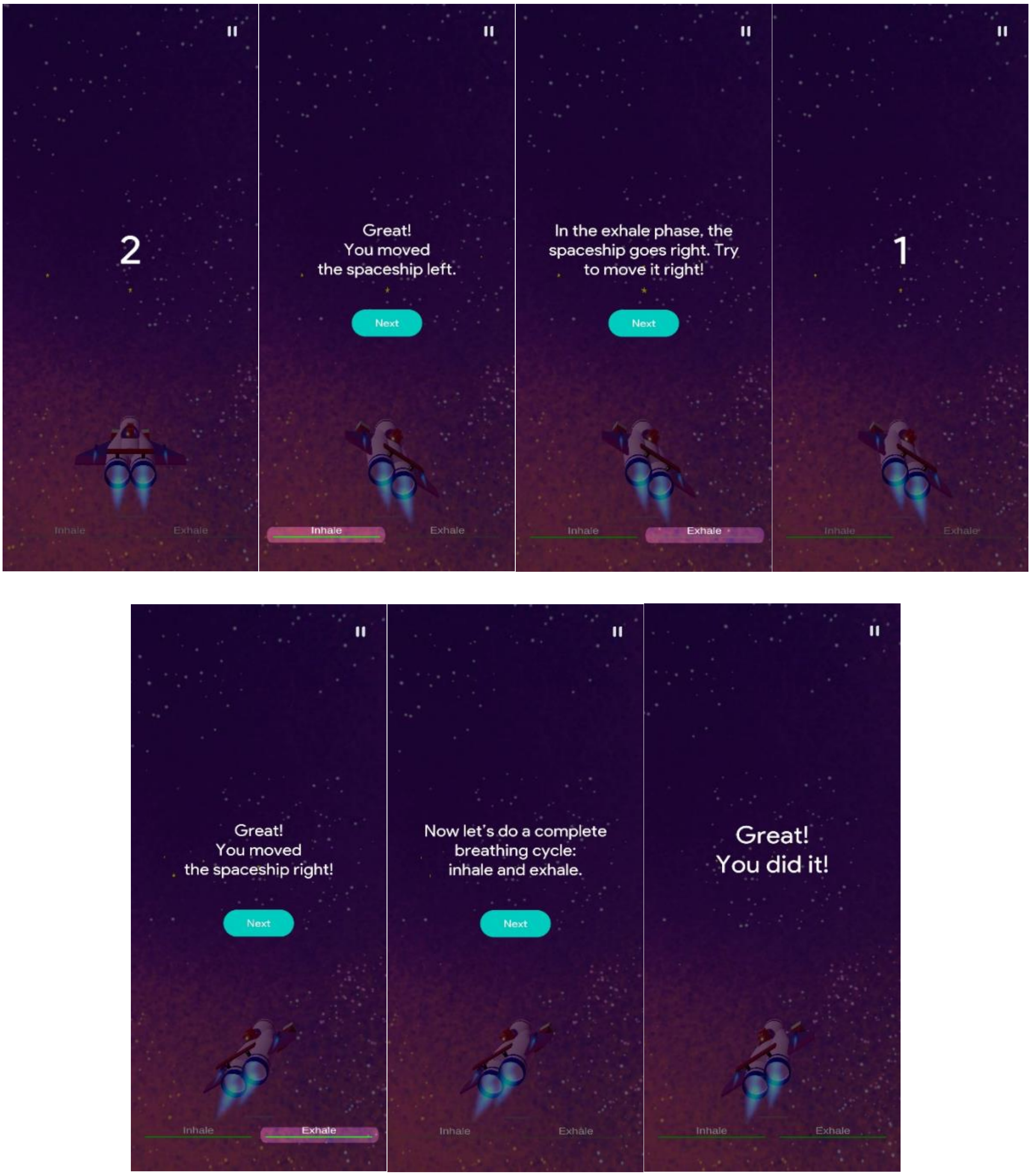



**Figure 53** Snapshot of the Practice Scene in "The Star Catcher" Breathing Game.

### 3.2.9 Exergames and "More Info" section

Building on the design of the Breathing Games, the Exergames category (including two fine motor skills and two full-body Exergames) also incorporates a "More Info" button, offering users easy access to scientific information about the category and each individual game. Each section includes icons for visual reference, improving readability, and a text-to-speech button[36] to enhance accessibility. Short descriptions have been added to each game's category button, giving players a quick understanding of the game's objectives. A three-dot button provides more in-depth information about each specific game (see **Figure 54**).

[36] The text-to-speech button is currently in the design phase and not yet implemented.

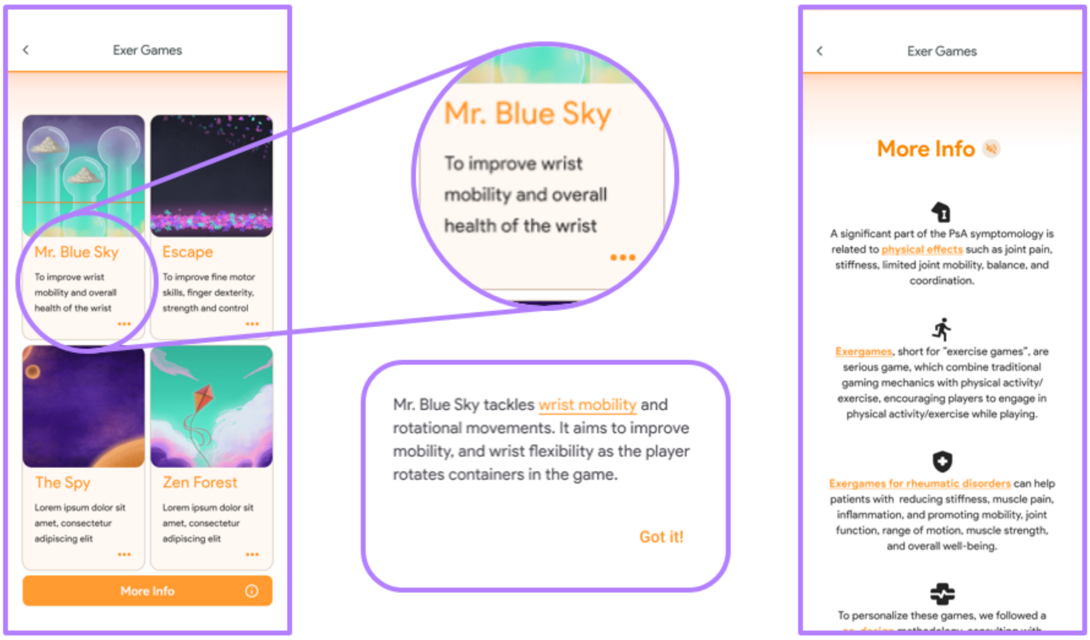



**Figure 54** Snapshot of the Exergames category menu and the "More Info" section

### 3.2.9.1 "Mr. Blue Sky" exergame

Mr. Blue Sky, the first fine motor skill game in the Exergames series, focuses on rotational hand movements. Players interact with a weather-themed system of tubes and containers filled with dark clouds, aiming to clear them by rotating the containers using the demonstrated hand gestures. As all containers rotate simultaneously, players must strategize to clear the clouds efficiently. This game effectively combines traditional wrist and hand mobility exercises with engaging gameplay, striking a balance between therapeutic benefits and entertainment.

#### 3.2.9.1.1 Menus

The menus in Mr. Blue Sky follow the structure of previous games but with an updated orange theme to match the Exergame category. Unlike previous games, there is no Stress Menu or calibration button, as they are specific to breathing games and not needed here. The skybox is updated to suit the game's atmosphere, and the **end game menus** keep a similar structure, featuring updated metrics such as pressure and movement duration, with speedometers for pressure and a counter for average duration for each hand (see **Figure 55**, **Figure 56**).

The **Difficulty level Menu** features three levels and no tutorial button, offering only a practice mode, as no breathing algorithm or calibration phase is required (see **Figure 57**). Future iterations may include more features.

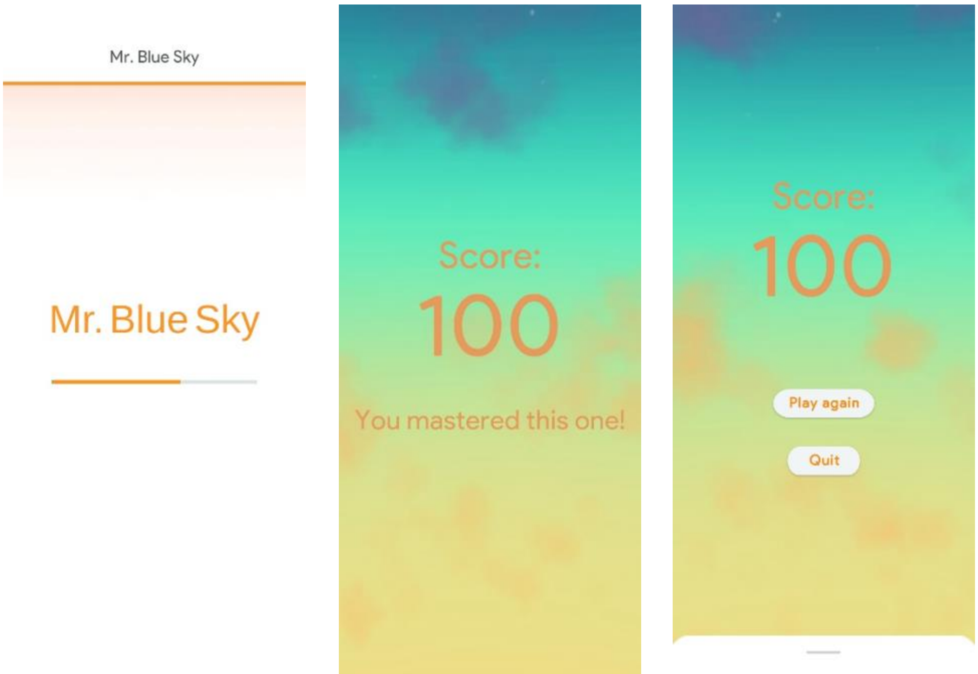



**Figure 55** Snapshot of the end game menu in "Mr. Blue Sky" Exergame, showcasing the player's score, performance message, and options to "Play Again" or "Quit."

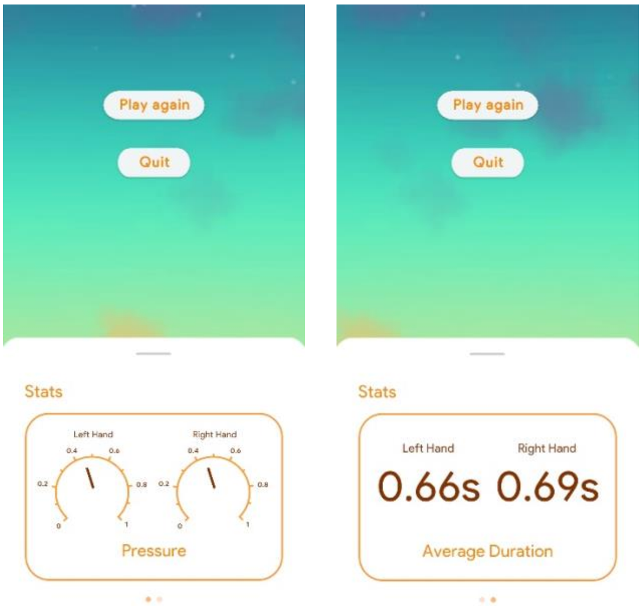



**Figure 56** Snapshot of the player stats screens in "Mr. Blue Sky" Exergame.

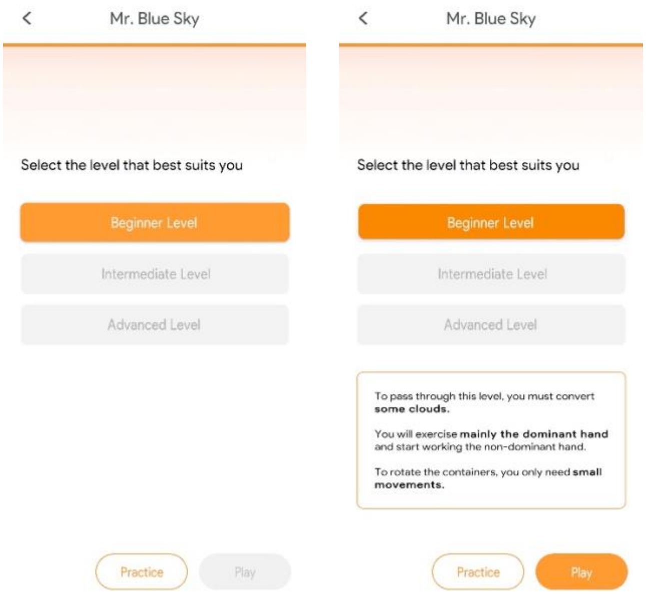



**Figure 57** Snapshot of the difficulty level screen in the "Mr. Blue Sky" Exergame, featuring the three difficulty levels (left) and a general panel with information about the rotation movements (right).

#### 3.2.9.1.2 Algorithm

The algorithm for Mr. Blue Sky is designed to detect and validate specific hand movements essential for the game mechanics, focusing primarily on rotational gestures. The process begins by detecting two touch inputs on the screen, which are tracked using Unity's Touch Input system. Once both touch points are detected, the algorithm captures and stores the initial positions of the fingers as 2D vectors ($V_{s1}$ for finger one and $V_{s2}$ for finger two). These positions represent the X and Y coordinates of the fingers at the moment they make contact with the screen.

After the initial positions are recorded, the algorithm then monitors the movement of the fingers until one or both are lifted from the screen. At the point of lifting, the final positions of both fingers are captured and stored in two new vectors ($V_{e1}$ and $V_{e2}$) to represent the end of the movement. This step allows the system to analyze the movement from start to finish, providing the data needed to validate whether the player has performed the intended hand gesture correctly.

To determine if the movement is circular, the algorithm calculates the midpoint between the two initial positions ($V_{s1}$ and $V_{s2}$), followed by the midpoint of the final positions ($V_{e1}$ and $V_{e2}$). Using these midpoints, the radius of the circle formed by the movement is calculated. The algorithm then compares the radius at the start and end of the gesture. For the movement to be classified as circular, the radii must be sufficiently close, with a margin of tolerance defined by a difficulty threshold. This ensures that even slight deviations from a perfect circular motion due to player skill or gameplay conditions do not result in a false rejection. If the radii do not match within the acceptable margin, a warning is triggered on the screen, informing the player that the movement was not circular.

Once the movement is validated as circular, the algorithm proceeds to determine the direction of rotation. The direction is determined by calculating the tangent of the movement at both the start and end positions of the fingers. The tangent is calculated by finding the difference between the Y coordinate of the finger's position and the center of the circle (derived from the midpoint of the initial positions), and then dividing this difference by the X coordinate difference. This process is repeated for each finger, and the resulting tangent values are used to compute the angular displacement of each finger from the start to the end of the gesture.

The algorithm then checks whether both fingers have rotated in the same direction and by the required minimum angular displacement, as defined by the current difficulty setting. If both conditions are met (same direction and sufficient displacement), the movement is accepted, and the game logic is updated to reflect the player's actions. However, if these conditions are not satisfied, the algorithm will reject the movement and display a warning to the player. This ensures that the player follows the intended movement pattern for each game challenge.

To further improve the player experience, the algorithm only considers the starting and ending points of the movement in its current implementation. This allows players to perform any intermediate gestures, as long as the start and end positions are correct. However, this approach has its limitations, as it does not continuously monitor the movement in real-time. To address this, a future version of the algorithm could incorporate a more dynamic approach by continuously checking the movement during its performance or conducting verification at regular intervals (e.g., every few seconds) to ensure that the movement remains consistent with the intended pattern. This change would improve accuracy and prevent potential errors during complex or fast-paced movements.

#### 3.2.9.1.3 Scene

The scene in Mr. Blue Sky consists of several key elements designed to create an engaging and dynamic environment. The weather station features three main pipes (two long and one shorter) with rotating semi-spheres at both ends, along with a central portal that converts clouds. Birb, a character from the iPROLEPSIS Games World, is placed on a special platform and assists players by indicating which hand to use, with his animations and platform designed by Marta Vicente. The clouds, created using Unity's Particle System, change colour as they pass through the portal, transitioning smoothly from dark to a range of colours in the iPROLEPSIS colour scheme. The number of clouds is dynamically generated, and their positions are pseudorandomized to descend gradually as the game progresses. The skybox and lighting are updated to match the game's atmosphere, and the camera setup is reused from previous scenes. All elements work together to shape the gameplay experience (see **Figure 58**).

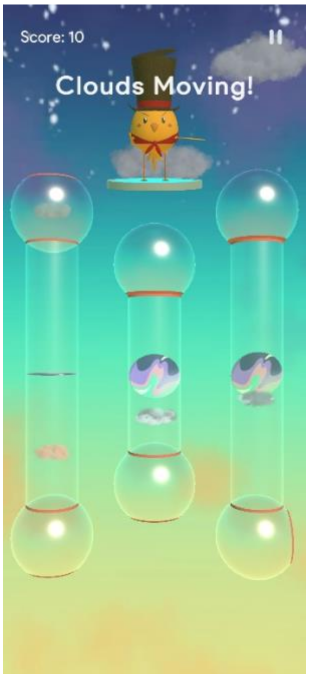



**Figure 58** Snapshot showing the first few seconds of gameplay in the in the "Mr. Blue Sky" Exergame.

#### 3.2.9.1.4 Game

Mr. Blue Sky is a puzzle game designed to engage PsA patients in therapy exercises through hand movements. The game revolves around rotating containers (semi-spheres) in a pipe system to guide clouds down through various stages. The containers rotate in 90º steps, either clockwise or counterclockwise, and the player must align them to allow clouds to move through the system. Each successful movement triggers a short animation and sound effect.

Gameplay Flow:

- The game starts with randomly placed clouds and containers. The objective is to rotate the containers to create an opening for the clouds to move downward.
- Players need to rotate the containers at the top and bottom of the pipes to align them correctly.
- The containers rotate in 90º increments, which corresponds to specific hand movements, promoting hand exercise for PsA patients.
- If a cloud is blocked, players can rotate the containers further or "pass" the movement with a tap to move the cloud downward.
- Warnings will appear if invalid movements are made (e.g., *“Wrong movement!”, “Not Enough Rotation”, “Clouds Moving!”, “Make a rotation to capture a cloud”*), providing guidance to the player.

Additional Features:

- The game includes a pause system (see **Figure 59**) and a mascot, Birb, who animates and signals the player on which hand to use. The hand preference (left or right) is initially set in the game.
- Birb's animations are triggered after successful moves and indicate the required hand for the next action.

- The game uses Unity Coroutines[37] for managing animations, cloud movement, warnings, and other transitions.

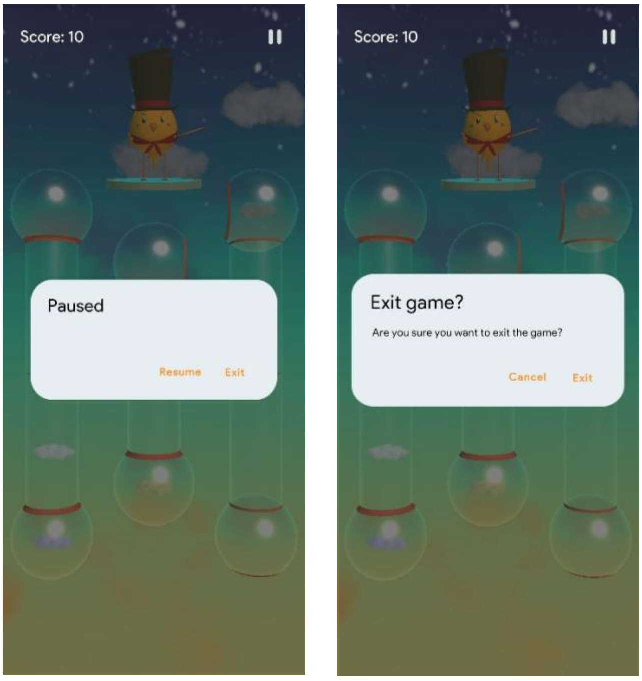



**Figure 59** Snapshot displaying the pause system in the "Mr. Blue Sky" Exergame.

#### 3.2.9.1.5 Game orientation & game to menu transition

Mr. Blue Sky is designed for vertical screen orientation to complement the downward flow of the clouds, making the gameplay intuitive and visually aligned with the mechanics. The vertical layout efficiently accommodates the required screen space for the main objects. Smooth scene transitions, consistent with those in earlier games, ensure a seamless user experience.

#### 3.2.9.1.6 Difficulty levels

Mr. Blue Sky includes three difficulty levels—Beginner, Intermediate, and Advanced—that adjust gameplay elements to provide a progressive challenge. Unlike previous games, there is no 'Error' metric for adjustment; instead, difficulty impacts the following:

1. Number of Clouds: Higher difficulty levels introduce more clouds to manage.
2. Required Rotation Angle: The minimum angle for valid rotations increases with difficulty.
3. Algorithm Precision: Movements must be more precise as the acceptance threshold tightens.
4. Hand Usage: Reliance on the player's dominant hand decreases in higher levels.

Difficulty Level details:

- Beginner: 10 clouds, 15º rotation, 25% non-dominant hand, 75% dominant hand.
- Intermediate: 15 clouds, 25º rotation, 50% non-dominant hand, 50% dominant hand.
- Advanced: 20 clouds, 40º rotation, 50% non-dominant hand, 50% dominant hand.

[37] https://docs.unity3d.com/Manual/coroutines.html

Unity's player preferences store the selected difficulty level, ensuring consistent adjustments across gameplay.

#### 3.2.9.1.7 Audio

Mr. Blue Sky incorporates a variety of carefully chosen audio tracks and sound effects to enhance player immersion:

1. Main Soundtrack: Inspired by the desert-like atmosphere of the skybox, a relaxing, free-to-use track from YouTube was selected, edited with Audiomass, and enhanced with fade-ins and fade-outs.
2. Semi-Sphere Movements: The sound of a boulder being dragged was used, providing a surprising yet fitting complement to the glass-like material of the semi-spheres.
3. Cloud Transformation Sound: A magical portal sound was sourced from Itch.io, designed to evoke the feeling of crossing a mythical gateway. The game uses three audio players to manage overlapping sounds when multiple clouds transform simultaneously.
4. Point Scoring Sound: A free, positive sound plays when clouds exit the screen and a point is scored, also managed by three audio players for smooth playback during overlap.
5. Birb's Voice and Instructions: A distinct bird sound from an AI library[38] was chosen to represent Birb, avoiding ambient noise issues in real recordings. An audio cue is included to guide players on which hand to use.
6. Winning Sound: The victory sound is reused from The Kite game.

These audio elements were curated and edited to match the thematic and functional needs of the game, ensuring an engaging and seamless player experience.

#### 3.2.9.1.8 Data collected during gameplay

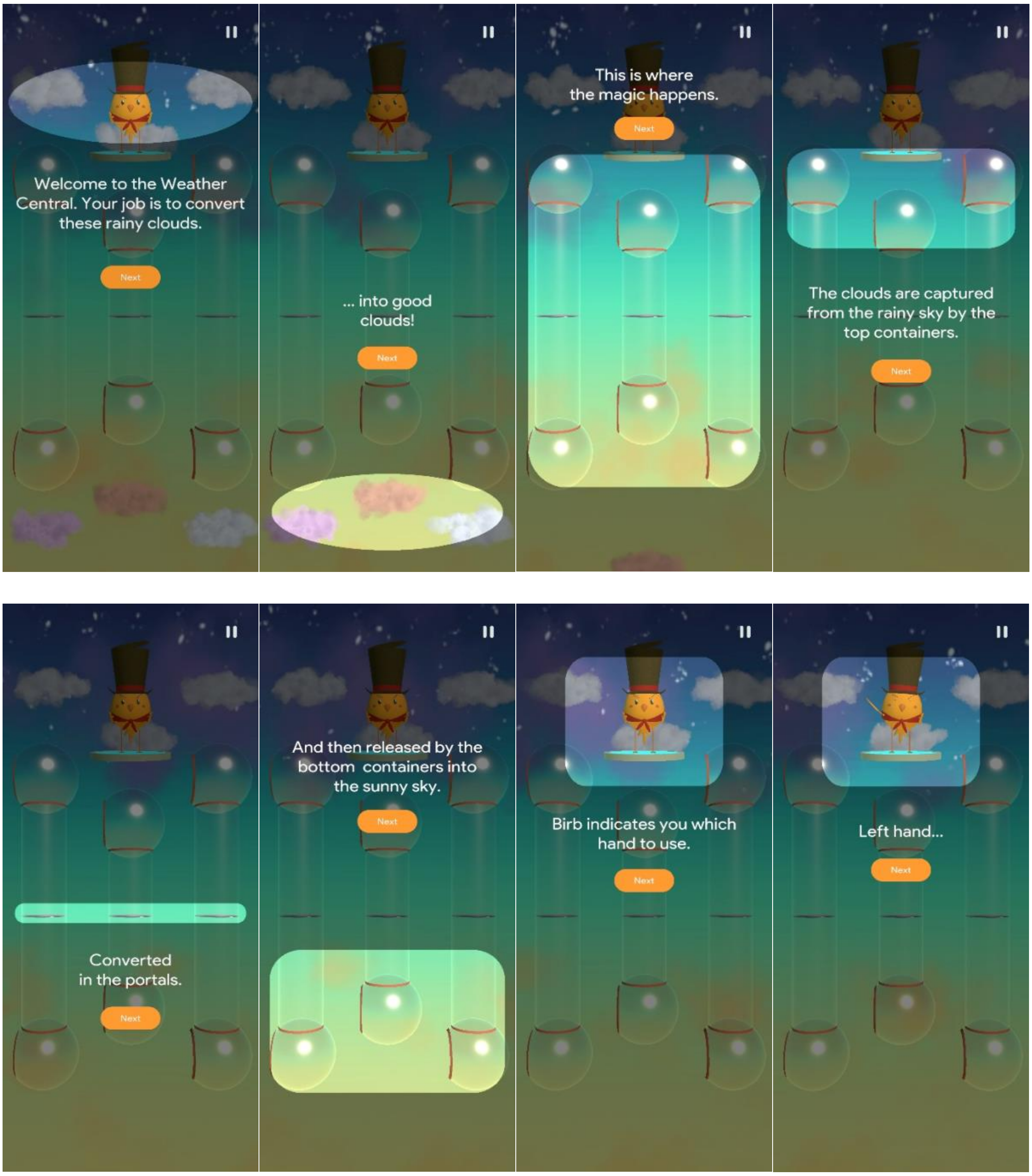
In the Mr. Blue Sky Exergame, performance data is collected with a focus on fine motor skills and hand movements. Two primary metrics are measured: the average pressure during hand rotation, and the average time taken to complete the game movements. Unity's touch API[39] is used to record touch pressure during each rotation, and the final value is calculated as the mean of these recordings. This process is performed separately for the right and left hands, maintaining distinct datasets for each. The average rotation time is measured by starting a timer when the movement begins and stopping it once the movement is validated, with the mean duration calculated for each hand.

Currently, the data collection process is in its prototype phase, allowing for future improvements. The dual-handed gameplay design ensures that performance data for both hands is tracked independently, providing a comprehensive analysis of the player's movements.

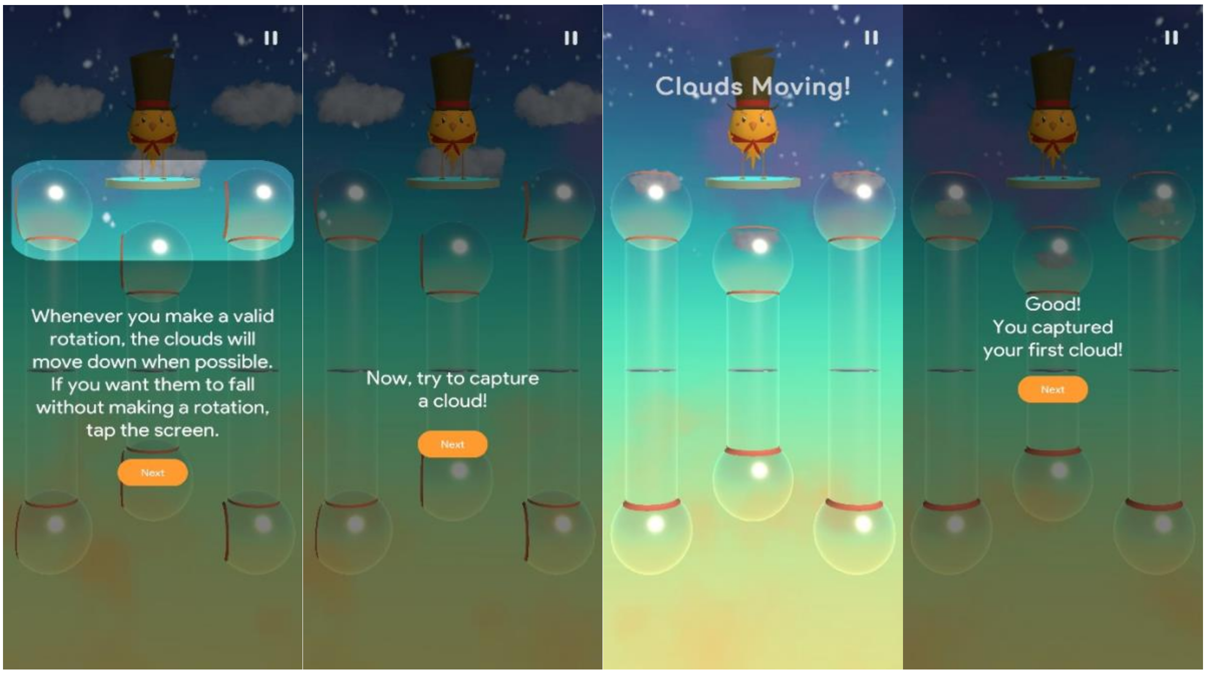
#### 3.2.9.1.9 Practice scene

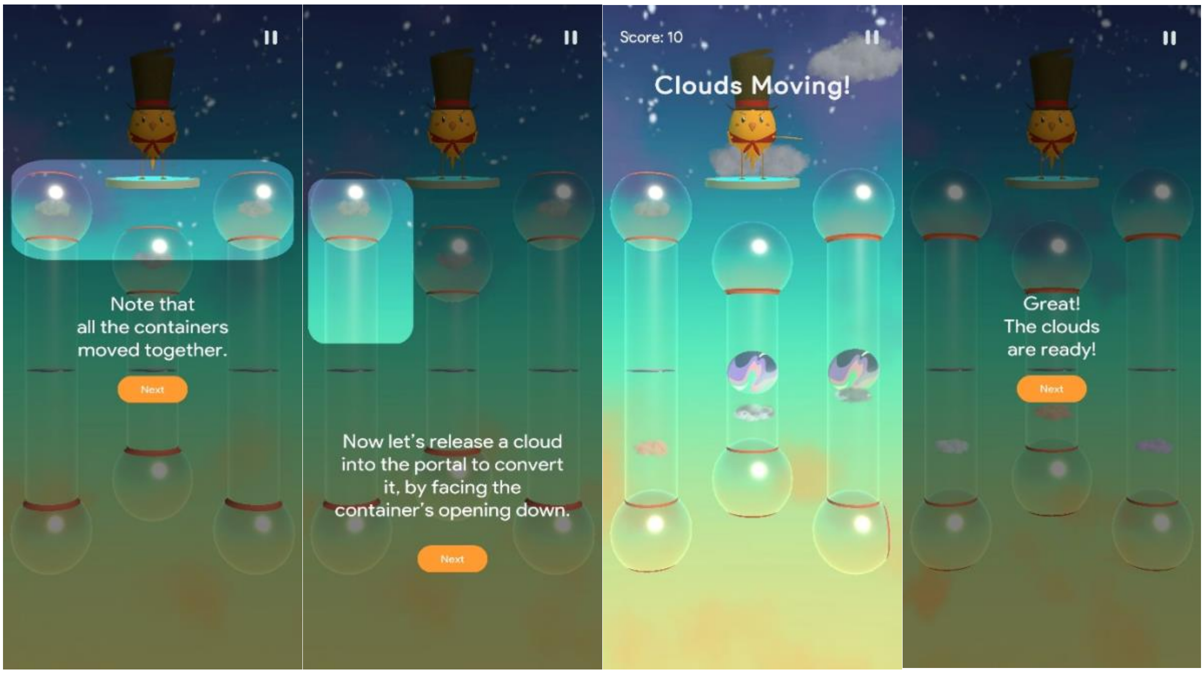
Mr. Blue Sky includes a practice scene that serves as an extended tutorial, as there is no separate tutorial scene. This larger practice environment uses the same panel mechanics as previous serious games, chosen for their simplicity and reusability. The scene features a controlled setup with three clouds moving through separate pipes, allowing players to practice the core mechanics in a manageable space before transitioning to the more challenging full game (see **Figure 60**). Unlike the main game, this practice scene does not employ the breathing algorithm, focusing instead on introducing the gameplay fundamentals.

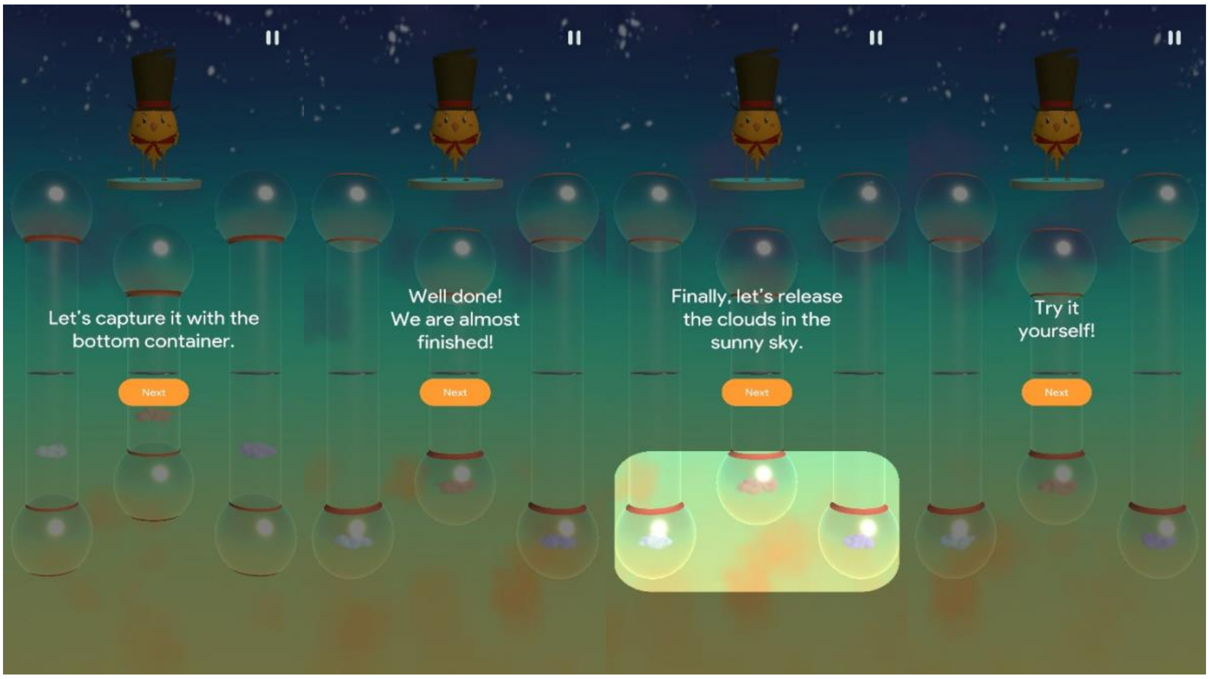
[38] https://experiments.withgoogle.com/ai/bird-sounds/view/
[39] https://docs.unity3d.com/ScriptReference/Touch.html


Welcome to the Weather Central. Your job is to convert these rainy clouds.
Next
... into good clouds!
Next
This is where the magic happens.
Next
The clouds are captured from the rainy sky by the top containers.
Next
Converted in the portals.
Next
And then released by the bottom containers into the sunny sky.
Next
Birb indicates you which hand to use.
Next
Left hand...
Next


.. or right hand.
Next
As long as Birb is holding his wing up, you must keep using that hand.
Next
To capture a cloud, you must rotate the container so that its opening faces up.
Next
You rotate a container by doing the rotation movement with two fingers in any space of the screen.
Next


Whenever you make a valid rotation, the clouds will move down when possible. If you want them to fall without making a rotation, tap the screen.
Next
Now, try to capture a cloud!
Next
Clouds Moving!
Good!
You captured your first cloud!
Next


Note that
all the containers
moved together.
Next
Now let's release a cloud
into the portal to convert
it, by facing the
container's opening down.
Next
Score: 10
Clouds Moving!
Great!
The clouds
are ready!
Next


Let's capture it with the
bottom container.
Next
Well done!
We are almost
finished!
Next
Finally, let's release
the clouds in the
sunny sky.
Next
Try it
yourself!
Next

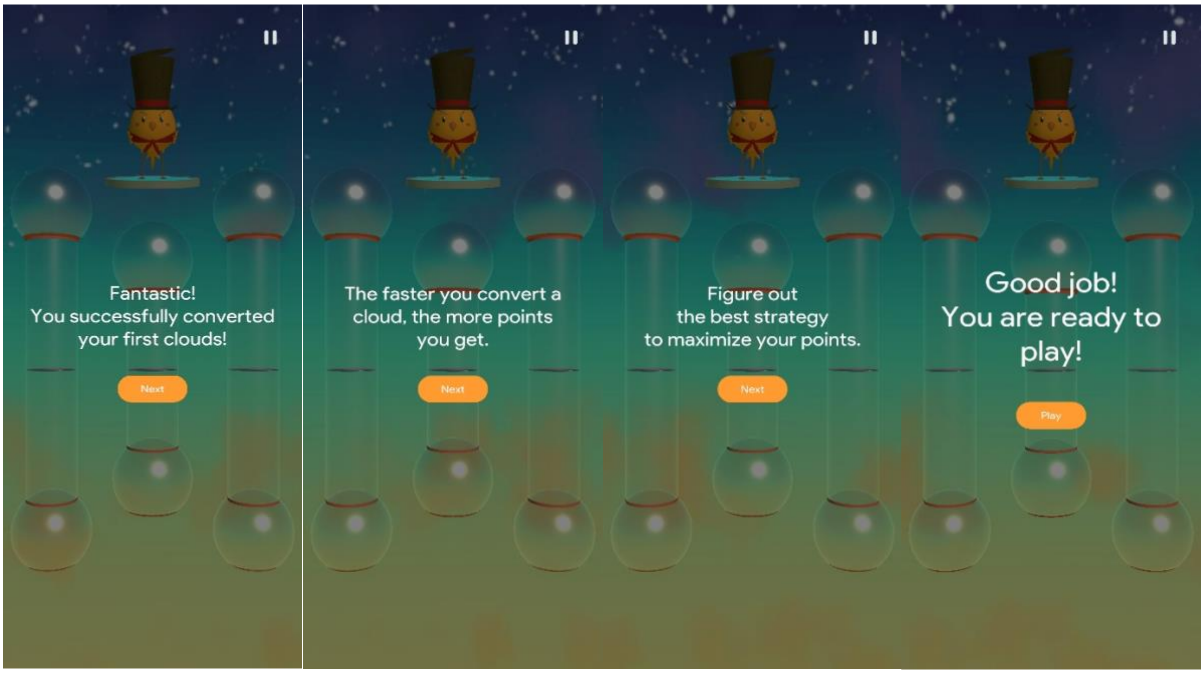



**Figure 60** Snapshot of the Practice Scene in "Mr. Blue Sky" Exergame.

### 3.2.9.2 "Escape" exergame

The Escape Exergame includes a character named Kel, who is trapped in a network of dark caves. The player's goal is to guide Kel to safety by completing mini-games in randomly selected sub-rooms and caves, making each playthrough unique.

Core Gameplay Mechanics

- Mini-Games: Completing each mini-game rewards the player with a "clue" encased in crystal. Collecting all clues unlocks the final code needed to escape.
- Randomization: Mini-games are chosen randomly, adding replayability.

Mini-Games Overview

- Mini-game 1 (Clear the Path): Remove rocks blocking Kel's way.
- Mini-game 2 (Platform Game): Navigate moving platforms to cross a pit.
- Mini-game 3 (Water Game): Fill a pit with water by pressing the screen.
- Mini-game 4 (Puzzle Game): Solve a rotation-based puzzle to reveal a clue.
- Mini-game 5 (Memory Game): Match cards in a classic memory format.
- Mini-game 6 (Find Clue Game): Search for a hidden clue inside a box.
- Mini-game 7 (Rotate Code Game): Use a rotary lock to unlock a door.
- Mini-game 8 (Keypad Code Game): Enter the final code from collected clues to escape.

This Exergame, ambitious in scope, demonstrates advanced game design and offers the potential for future expansion with eventual additional mini-games.

#### 3.2.9.2.1 Menus

The menus in Escape, the second Exergame, are designed to closely look like those from Mr. Blue Sky. Main menus include the Loading Menu, Main Menu, and Loading Score Menu, as shown in **Figure 61**.

The **End Game Menu** also follows a similar structure, including a main panel with sub-panels for additional information (see **Figure 62**).

The **Difficulty level Menu** mirrors the one in Mr. Blue Sky, with play and practice options and three difficulty levels, along with the familiar alerts (see **Figure 63**).

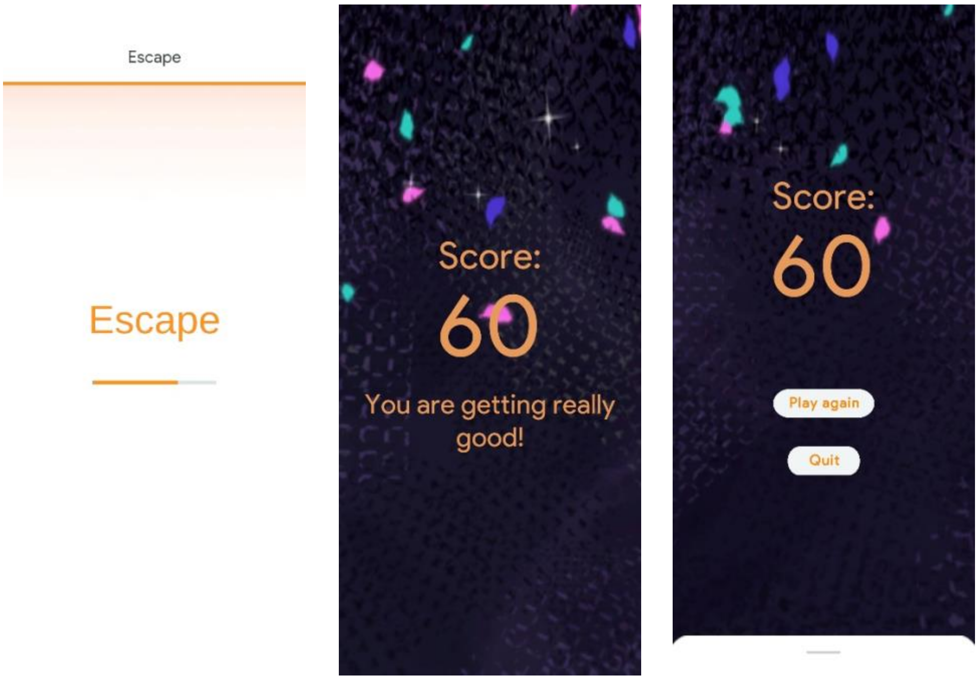



**Figure 61** Snapshot of the end game menu in "Escape" Exergame, showcasing the player's score, performance message, and options to "Play Again" or "Quit."

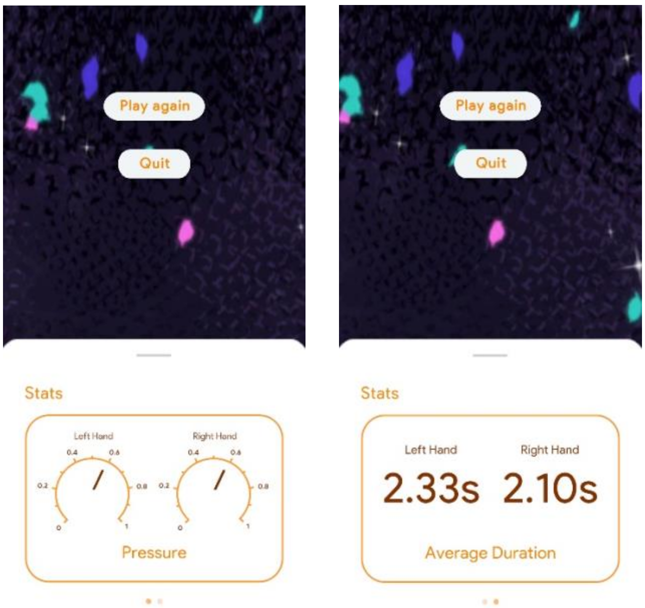



**Figure 62** Snapshot of the player stats screens in "Escape" Exergame.

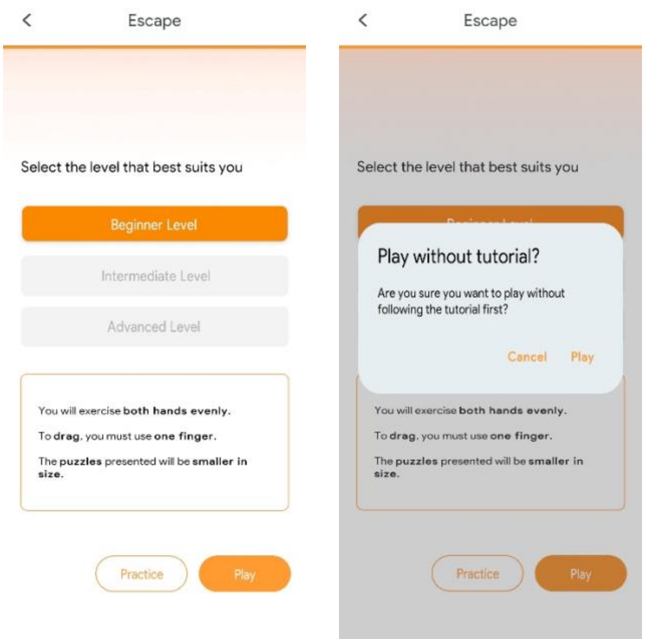



**Figure 63** Snapshot of the difficulty level screen in the "Escape" Exergame, showing the three difficulty levels including a general panel with information about the hand movements (left), and the warning regarding tutorial completion (right).

#### 3.2.9.2.2 Algorithms

The Escape Exergame employs multiple sub-algorithms tailored to the mechanics and exercise detection for each mini-game. These algorithms were developed using Unity tools to ensure smooth and realistic gameplay.

Mini-Game Algorithms

**1. Clear the Path**

- Mechanic: Remove rocks by clicking and dragging.
- Implementation: Raycasting detects rock objects. Finger movements adjust the rock's X and Y positions, keeping Z constant. Unity's Rigidbody[40] component adds realistic motion.

**2. Platform Game**

- Mechanic: Move Kel left, right, or jump between platforms.
- Implementation: A universal movement script manages clicks for direction and upward swipes for jumping, with jump force proportional to swipe distance.

**3. Water Game**

- Mechanic: Raise water by tapping and row a boat by sliding horizontally.
- Implementation: Raycasting detects taps within a target zone, while horizontal swipes simulate rowing.

**4. Memory Game**

- Mechanic: Match cards by selecting and pressing them.
- Implementation: Raycasting detects taps on specific card areas.

**5. Puzzle Game**

- Mechanic: Rotate and move puzzle pieces into position.

[40] https://docs.unity3d.com/ScriptReference/Rigidbody.html

- Implementation: A two-finger gesture centers the piece. A pinch gesture lifts it, and a rotation algorithm allows real-time rotation while fingers remain on the screen.

**6. Rotate Code Game**

- Mechanic: Turn a rotary combination lock.
- Implementation: Builds on the rotation algorithm from the Puzzle Game, updating the lock's position in real-time.

**7. Find Clue Game**

- Mechanic: Rotate an object to reveal a hidden clue.
- Implementation: Camera movement is tied to hand sliding, similar to jump detection.

**8. Keypad Code Game**

- Mechanic: Enter the final code using a 3D keypad.
- Implementation: Raycasting detects taps but does not require additional movement detection.

The following key development tools were used:

- Unity: Used for mechanics, motion detection, and interaction.
- Raycasting: Guarantees precise detection of player interactions.
- Rigidbody Component: Adds natural motion effects to objects.
- Rotation Algorithm: Reused from previous projects like Mr. Blue Sky.

This modular approach to algorithms allows for flexibility and scalability, enabling the addition of new mini-games in the future.

#### 3.2.9.2.3 Scene

The Escape scene is the most complex of the presented games so far, incorporating eight mini-games into one cohesive experience. These mini-games are centered around the player character, Kel, who interacts with unique scenarios while maintaining a consistent design. Each mini-game is loaded individually to optimize performance, with others deactivated until needed. The mini-games are chosen randomly, except the Keypad Code Game, which always serves as the final challenge.

**1. Core design Elements:**

- All mini-games share a corridor design with a 3D environment and 2D motion, illuminated by fluorescent flowers and gemstones.
- The player character, Kel, carries a glowing red crystal, providing dynamic lighting that enhances the cave-like atmosphere.
- Universal objects, like rotating gemstones and monoliths, add depth and detail to each mini-game.

**2. Mini-Games Overview:**

- Clear the Path: Players drag green movable cubes to clear a pathway, while pink cubes remain stationary.
- Platform Game: Inspired by Super Mario[41], this game involves jumping across moving platforms with varying heights.
- Water Game: Players raise water levels and navigate a raft across the scene.
- Puzzle Game: Features 2x2, 3x3, and 4x4 grids of puzzle pieces for assembly, displayed on a wooden plane.

[41] https://pt.wikipedia.org/wiki/Super_Mario

- Memory Game: Involves flipping cards to match pairs on grids of increasing difficulty (2x5, 3x4, 3x6).
- Find Clue Game: Players rotate objects to locate hidden clues within a wooden box.
- Rotate Code Game: Requires unlocking a gate by interacting with its rotating mechanism.
- Keypad Code Game: The final challenge, where players input a digital code to unlock a gate.

Lighting, animations, and pseudo-random object generation add a dynamic and immersive experience. Each mini-game's mechanics and assets, meticulously designed, contribute to the overall gameplay diversity (see **Figure 64**).

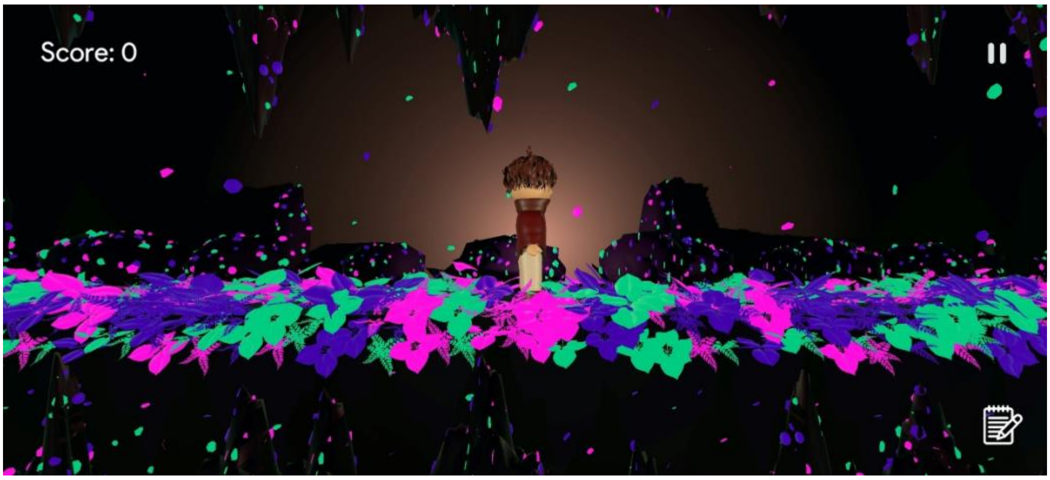



**Figure 64** Snapshot of gameplay in the "Escape" Exergame.

#### 3.2.9.2.4 Game

Escape is the most ambitious game created, integrating a complex system of mini-games and advanced mechanics. Spanning three months to complete, it represents a culmination of game development knowledge and serves as a foundation for standalone games in the future. Players navigate through different randomly selected mini-games and conclude with a fixed game, "Keypad Code Game." Collecting gemstones containing code segments is central to progression.

Core Mechanics:

- Player Movement: The main character, Kel, is controlled via simple gestures—tapping for movement and diagonal sliding for jumps. Unity's Rigidbody component handles gravity and collisions, complemented by a respawn mechanic for recovery.
- Animation: Kel's animations (idle, moving, jumping) is managed in Unity Animator within the movement script.
- Sound Design: An auditory feedback system enhances immersion.
- UI: Includes pause menus, score labels, and an interactive notebook recording codes, accessed via a UI icon.

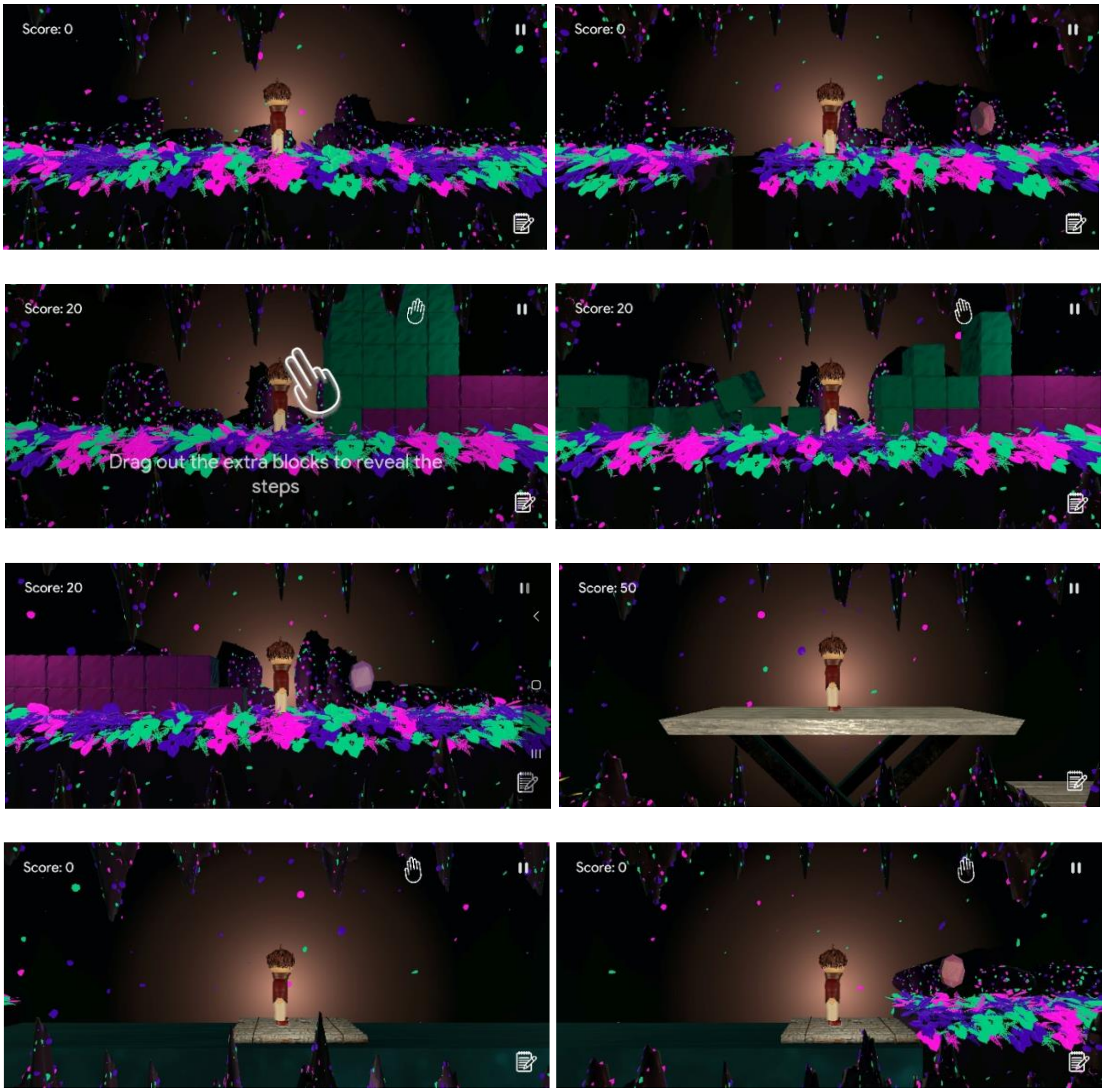
Mini-Games (see **Figure 65**):

- Clear the Path: Players drag obstacles to clear Kel's path and collect a gemstone. Encourages general hand and finger movement.
- Platform Game: Requires precise timing to navigate moving platforms over a pit, with a revive feature upon failure.

- Water Game: Players tap to raise water levels, guiding a raft to the gemstone.
- Puzzle Game: Focuses on hand exercises using pinch and rotation movements to assemble a puzzle and reveal a clue.
- Memory Game: A classic memory card game, challenging players to match pairs.
- Find Clue Game: Players rotate objects within a box to locate hidden clues, utilizing Unity's raycasting and colliders.

Transitions and Progression:

The Game Manager ensures smooth gameplay by coordinating transitions between mini-games. Players progress through the sequence, ultimately reaching the final challenge, the "Keypad Code Game," which concludes the adventure once all code segments are collected. Escape masterfully blends engaging gameplay with therapeutic potential, emphasizing playability while subtly encouraging refine motor movements. Each mini-game presents unique challenges, fostering diverse and dynamic player interactions. By integrating physical and mental exercises into its gameplay, "Escape" delivers an engaging and purposeful experience tailored to its players.



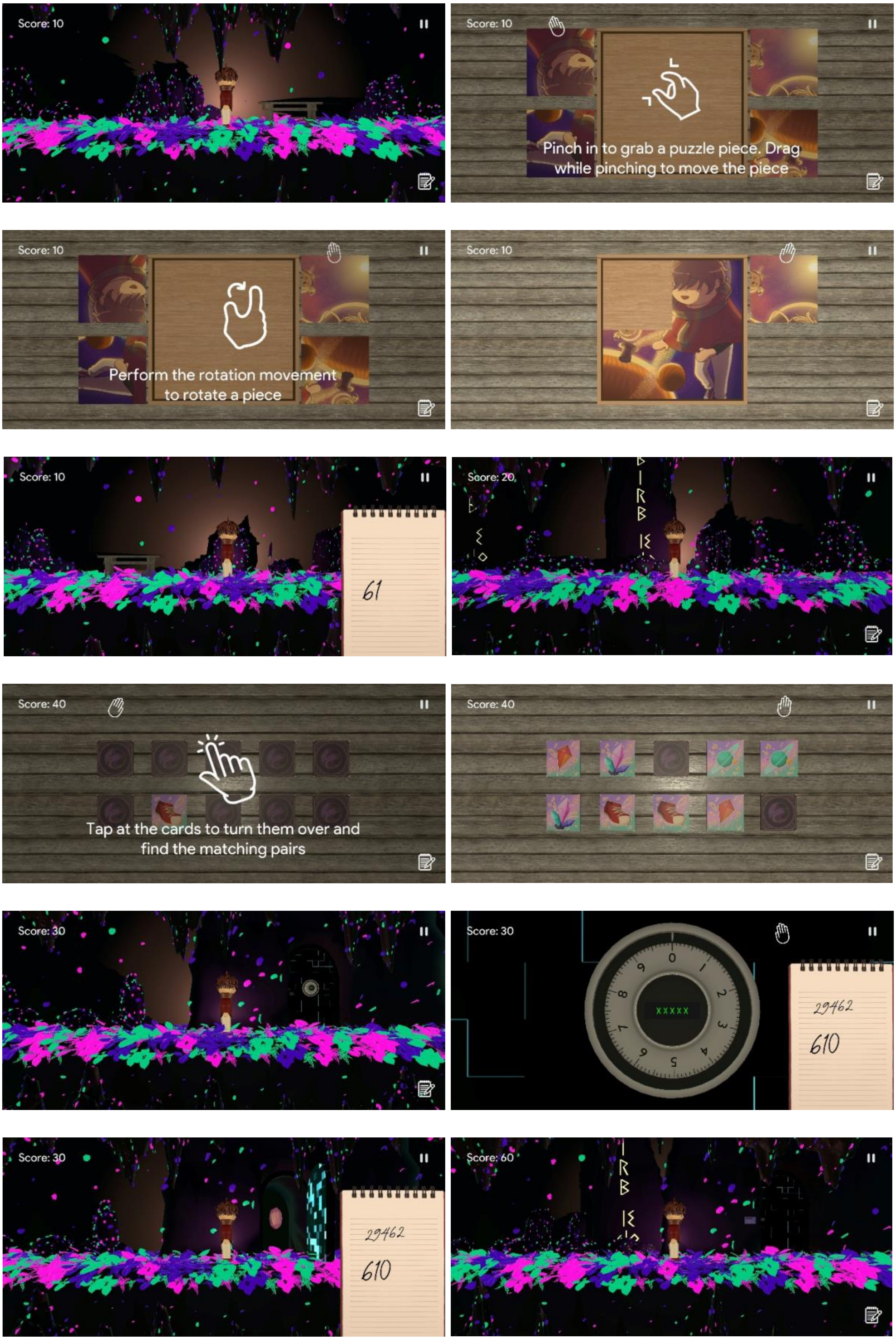

Score: 10
Score: 10
Pinch in to grab a puzzle piece. Drag while pinching to move the piece
Score: 10
Perform the rotation movement to rotate a piece
Score: 10
Score: 10
61
Score: 20
Score: 40
Tap at the cards to turn them over and find the matching pairs
Score: 40
Score: 30
Score: 30
XXXXX
29462
610
Score: 30
29462
610
Score: 60

**Figure 65** Snapshots showcasing the different mini-games included in the "Escape" Exergame.

The game also features a pause system, as illustrated in **Figure 66**.

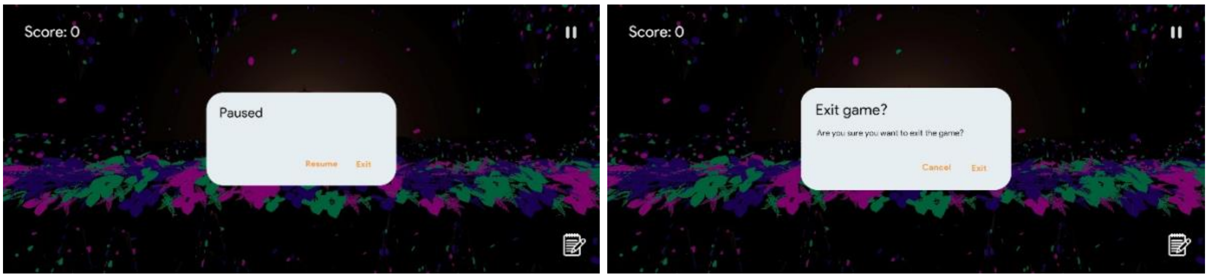



**Figure 66** Snapshot displaying the pause system in the "Escape" Exergame.

### 3.2.9.2.5 Game orientation & game to menu transition

Escape follows the design pattern of previous games by returning to a horizontal display, in contrast to the vertical orientation used in Star Catcher and Mr. Blue Sky. The horizontal orientation complements the game's focus on Kel's exploration of a cave, aligning with the desired exploration style and avoiding vertical motion. Consistent screen transitions are maintained, providing a seamless experience for players.

### 3.2.9.2.6 Difficulty levels

Escape includes three difficulty levels—Beginner, Intermediate, and Advanced—that adjust gameplay elements to provide a progressive challenge.

Difficulty Level details:

- Beginner: Players perform dragging movements using one finger, simplifying the interaction and making it more accessible for beginners or individuals with limited dexterity. The puzzles presented at this level are smaller in size, requiring fewer steps to complete and ensuring that players can gain confidence in their abilities before advancing to more challenging tasks.
- Intermediate: Players perform dragging movements using two fingers, introducing a moderate increase in complexity. This fosters coordination between both fingers, encouraging the development of fine motor skills. The puzzles are medium in size, requiring additional effort and problem-solving compared to the beginner level, while remaining manageable for intermediate players.
- Advanced: Players perform dragging movements using two fingers, with more precise and coordinated interactions required. This level challenges the player's dexterity and hand-eye coordination to the fullest. The puzzles are larger in size, involving more complex arrangements and multiple steps to solve, providing an engaging challenge for players with advanced motor skills.

### 3.2.9.2.7 Audio

The sound design for Escape involved sourcing various audio elements to enhance the gameplay experience. The game features two distinct soundtracks: one for gameplay and another for the menus. The gameplay soundtrack, primarily a subterranean cave ambiance, was sourced from YouTube and minimally edited. The menu soundtrack came from Itch.io, a platform previously used for other games.

Key sound effects include Kel's footsteps, sourced from Uppbeat.io[42], with extra effort put into synchronizing the steps with Kel's movements. For Kel's jump, separate sounds for the leap and landing were sourced, with the leap sound edited to remove an unwanted grunt. Writing on paper when interacting with the notebook was complemented by a sound found on YouTube, while the sound of glass shattering was used for the code pieces, followed by a writing sound for added realism.

For game mechanics, ticking sounds were added for the Rotate Code Game when rotating objects, and console button sounds were used in the Keypad Code Game. Both games share a system error sound for incorrect code inputs, while success sounds vary: a medieval door opening sound for Rotate Code and a system success sound for the Keypad Code Game.

In the Memory Game, a card-flipping sound was added, with the same success and error sounds from the Keypad Code Game used for game completion or incorrect pairs. A generic success sound from the Rotate Code Game was also used in both the Puzzle and Memory Games.

Additional sounds include a steam burst for the machines in the Platform Game and a calming revive sound from Uppbeat.io, signalling Kel's repositioning after falling. The traditional button click sound remained unchanged throughout.

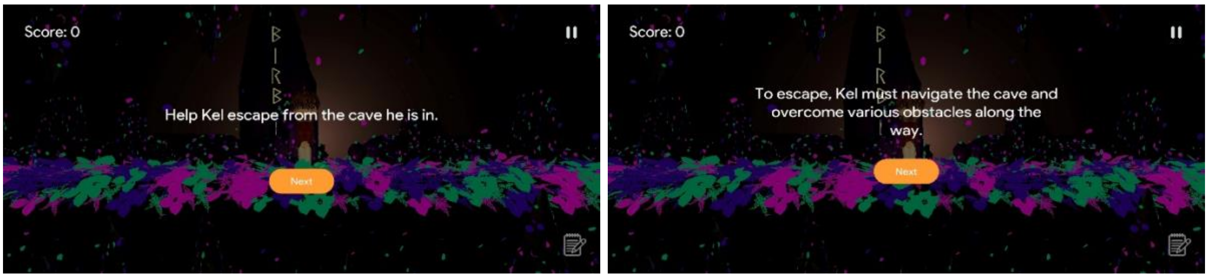
These carefully sourced and edited sound effects contribute to a more immersive and intuitive player experience.

### 3.2.9.2.8 Data collected during gameplay

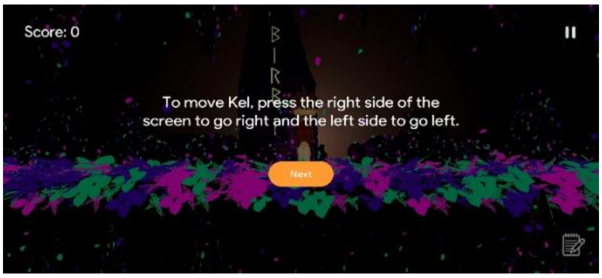
Game data collection, as with previous serious games, is planned but has not yet been implemented. The approach is expected to follow the structure of Mr. Blue Sky, initially focusing on rotation-based games and eventually incorporating metrics for other relevant fine motor skills, such as pinch-in and pinch-out movements.

### 3.2.9.2.9 Practice scene

Like the other games, Escapes includes a practice scene—a structured and controlled environment designed to help players become acquainted with the game mechanics prior to engaging in the main gameplay. **Figure 67** provides an illustration of the practice screen.

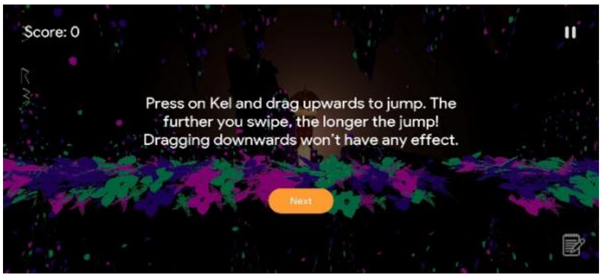


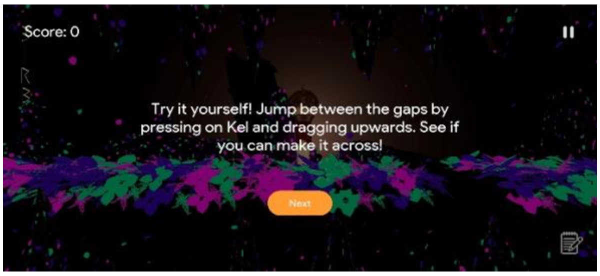

42 https://uppbeat.io/


Score: 0
To move Kel, press the right side of the screen to go right and the left side to go left.
Next

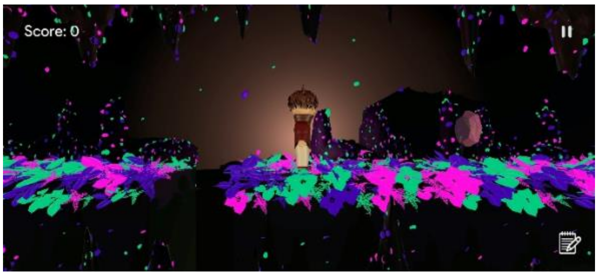

Score: 0
Give it a try!
Next


Score: 0
Well done!
Next

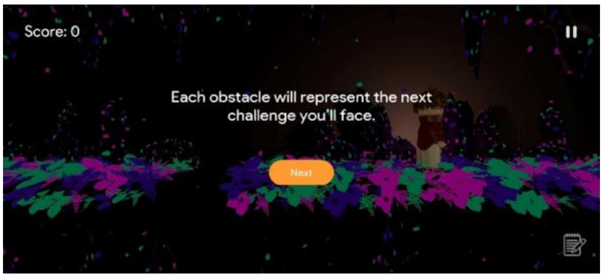

Score: 0
Press on Kel and drag upwards to jump. The further you swipe, the longer the jump! Dragging downwards won't have any effect.
Next

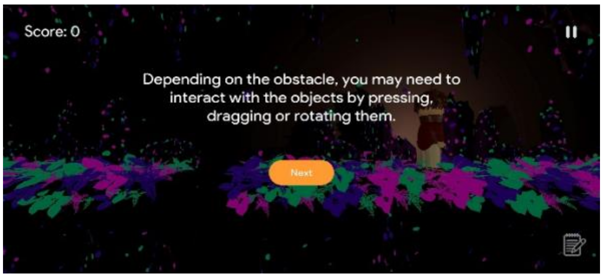

Score: 0
Try it yourself! Jump between the gaps by pressing on Kel and dragging upwards. See if you can make it across!
Next

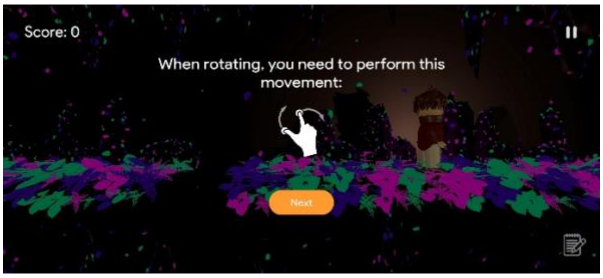

Score: 0
If you fall, don't worry — Kel will be brought back, ready for another try!
Next


Score: 0


Score: 0
Throughout the game, you may encounter obstacles in your path.
Next


Score: 0
Each obstacle will represent the next challenge you'll face.
Next


Score: 0
Depending on the obstacle, you may need to interact with the objects by pressing, dragging or rotating them.
Next


Score: 0
When rotating, you need to perform this movement:
Next


Score: 0
Once each obstacle is cleared, a clue will appear.
Next

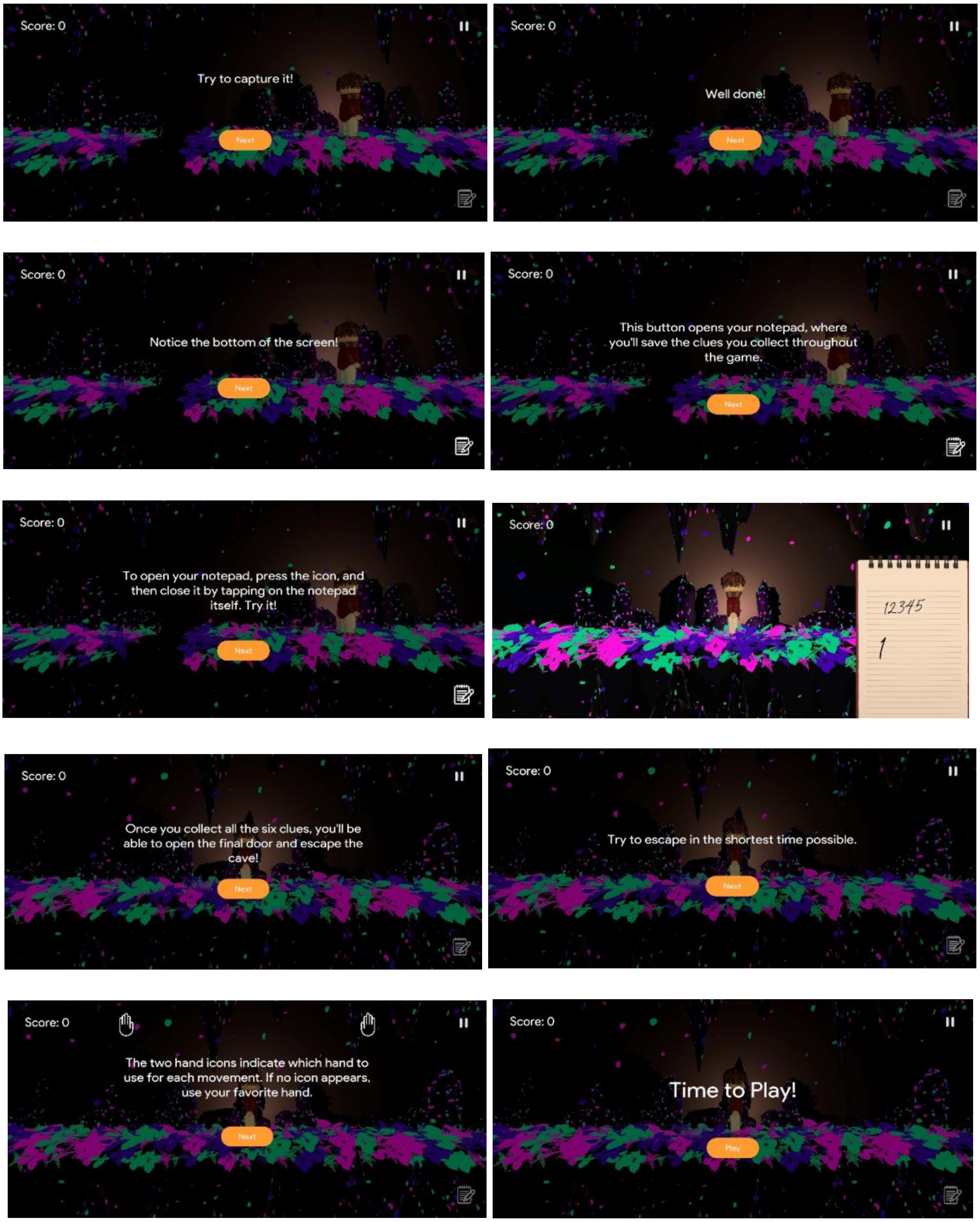



**Figure 67** Snapshots of the Practice Scene in "Escape" Exergame.

### 3.2.9.3 “Spy” exergame prototype

The "Spy" Exergame immerses players in an exciting mission where they must escape a villain’s lair by successfully completing a series of seven dynamic mini-games. Intending to use body-tracking technology, such as Mediapipe[43], the game requires the device —preferably

[43] https://ai.google.dev/edge/mediapipe/solutions/guide

a tablet— to be positioned at an appropriate distance to capture the player's full-body movements accurately. Each day of the week features four unique mini-games, strategically designed to target key fitness categories: mobility, balance, strength, and flexibility. This variety ensures a well-rounded and engaging physical activity experience, promoting both physical fitness and immersive gameplay. In particular:

1. Mini-game 1: Object Pairing
- Players use drag-and-drop movements to pair corresponding halves of objects on two moving walkways.
- Large and small fist movements are used to grab objects and join them.

2. Mini-game 2: Mirrored Catching and Hiding
- Players catch objects while navigating mirrored camera views.
- When alarms ring, players must squat or lunge to hide from enemies, resuming catching tasks after the enemies leave.

3. Mini-game 3: Staying Hidden
- Players hold specific postures to remain hidden from enemies, matching their body position to objects on the screen.

4. Mini-game 4: Container Control
- Flexion and extension movements are used to open and close container doors, capturing correct objects while avoiding wrong ones.

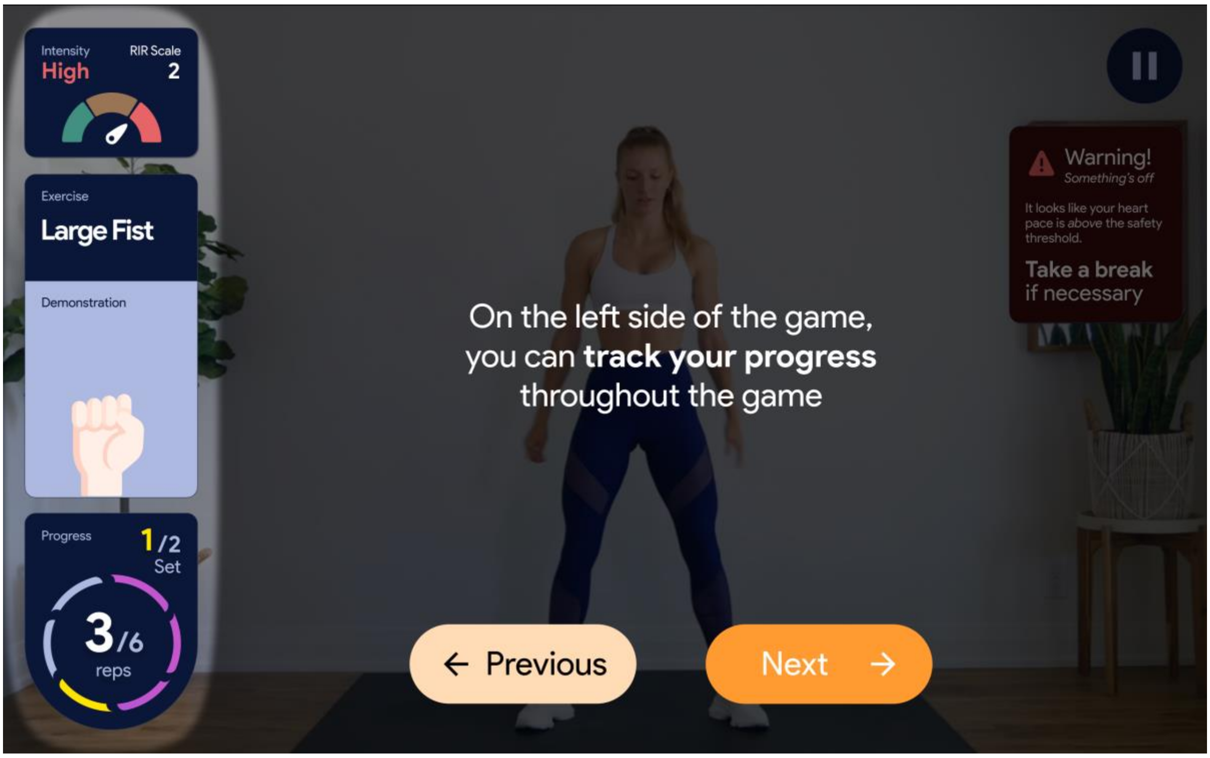
5. Mini-game 5: Side-specific Catching
- Players perform left or right exercises to catch objects fired to a specific side, using trunk and upper body flexion and extension.

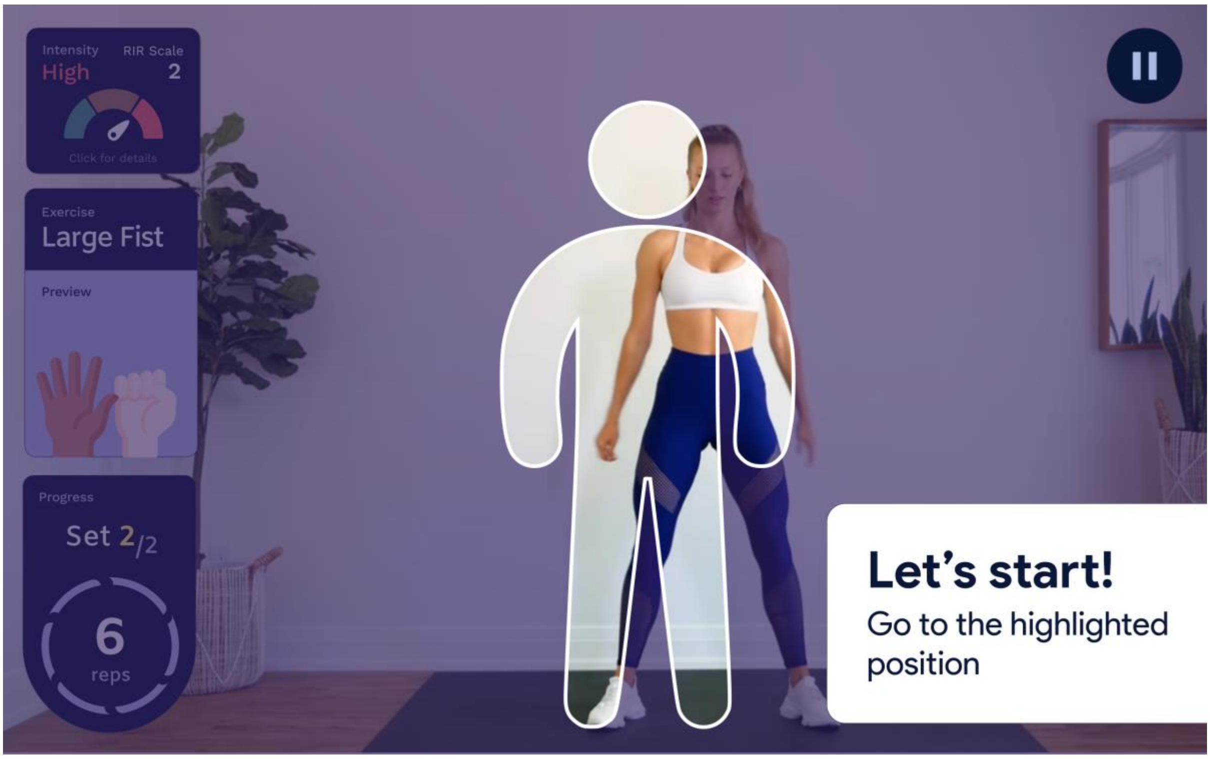
6. Mini-game 6: Obstacle Course
- Players march on the spot to move forward, switch tracks with arm movements, jump over obstacles with calf raises, and squat to go under barriers.

7. Mini-game 7: Rope Walking
- Players maintain balance while walking heel-to-toe on a virtual rope, avoiding falling by performing the exercise correctly.

Completing all mini-games for the day allows the player to escape the villain's lair. The combination of physical movements and game elements provides an enjoyable and functional fitness experience. The updated storyboard for the "Spy" exergame, which includes detailed narratives for each mini-game, is provided in Appendix 2. Updated Storyboard for the "Spy" exergame

**Figure 68–Figure 71** present the prototypes for the "Spy" exergame, showcasing key elements such as the main gameplay screen, the Pause system, the Rest Time screen, and the End-Game Results screen. These designs are still in the development phase and have not yet been implemented, serving as visual concepts that outline the intended user experience and gameplay flow.


Intensity
High
RIR Scale
2
Exercise
Large Fist
Demonstration
Progress
1/2
Set
3/6
reps
Warning!
Something's off
It looks like your heart pace is above the safety threshold.
Take a break if necessary
On the left side of the game, you can **track your progress** throughout the game
Previous
Next


Intensity
High
RIR Scale
2
Click for details
Exercise
Large Fist
Preview
Progress
Set 2/2
6
reps
Let's start!
Go to the highlighted position

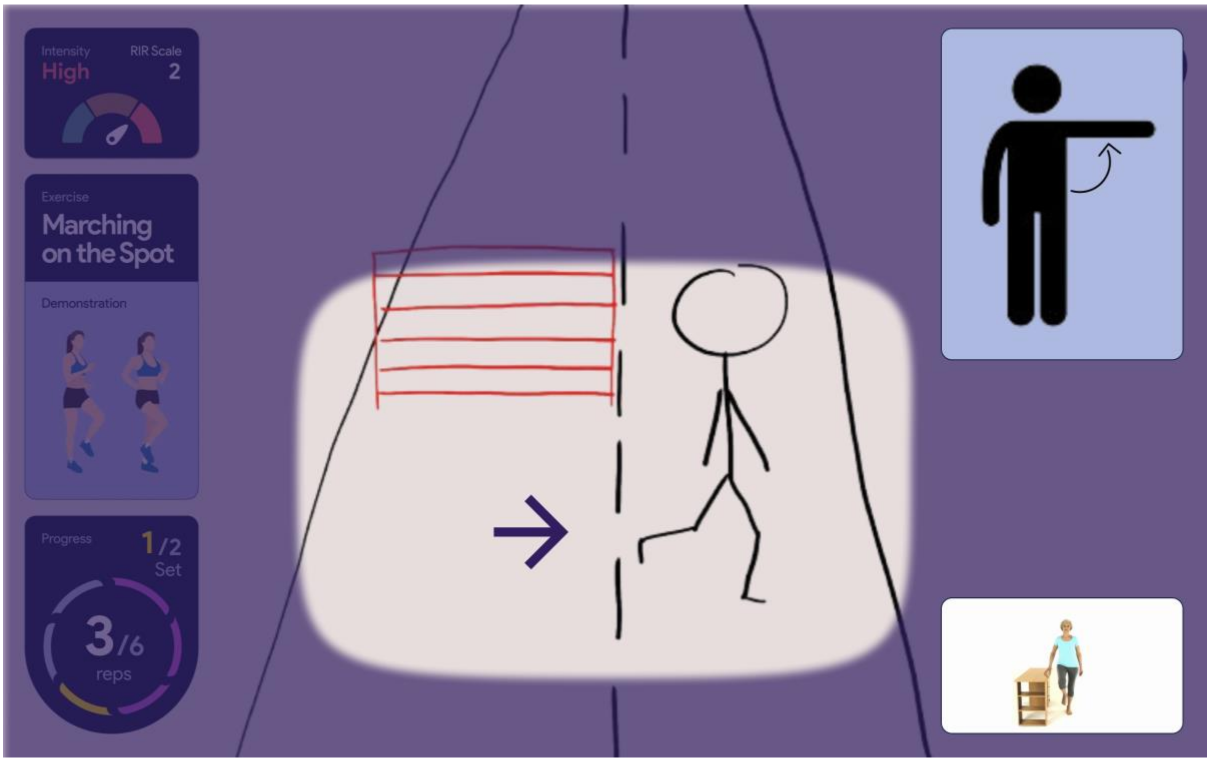



**Figure 68** Snapshot of the main gameplay screens in the "Spy" Exergame. It is important to note that multiple scenes are expected to be developed, considering the different game types (Mobility, Balance, Strength, and Flexibility exercises) outlined in Appendix 2. Updated Storyboard for the "Spy" exergame

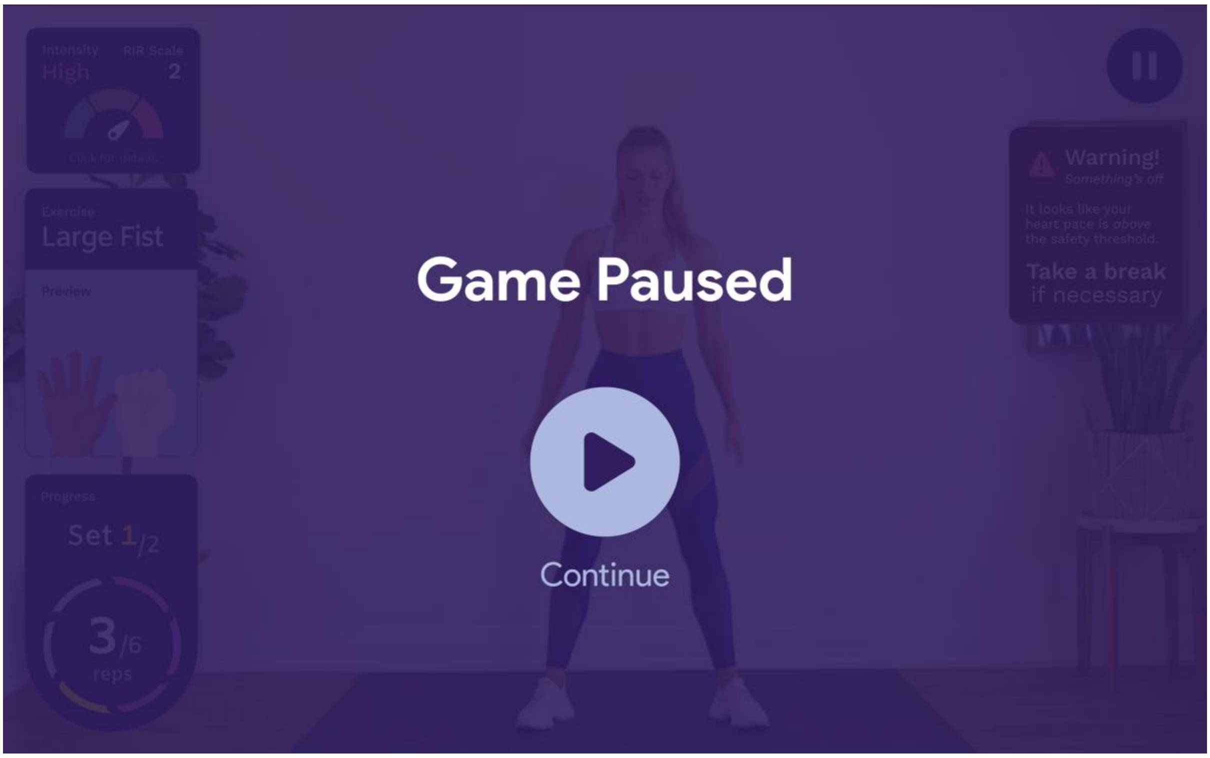



**Figure 69** Snapshot showcasing the Pause system in the "Spy" Exergame.

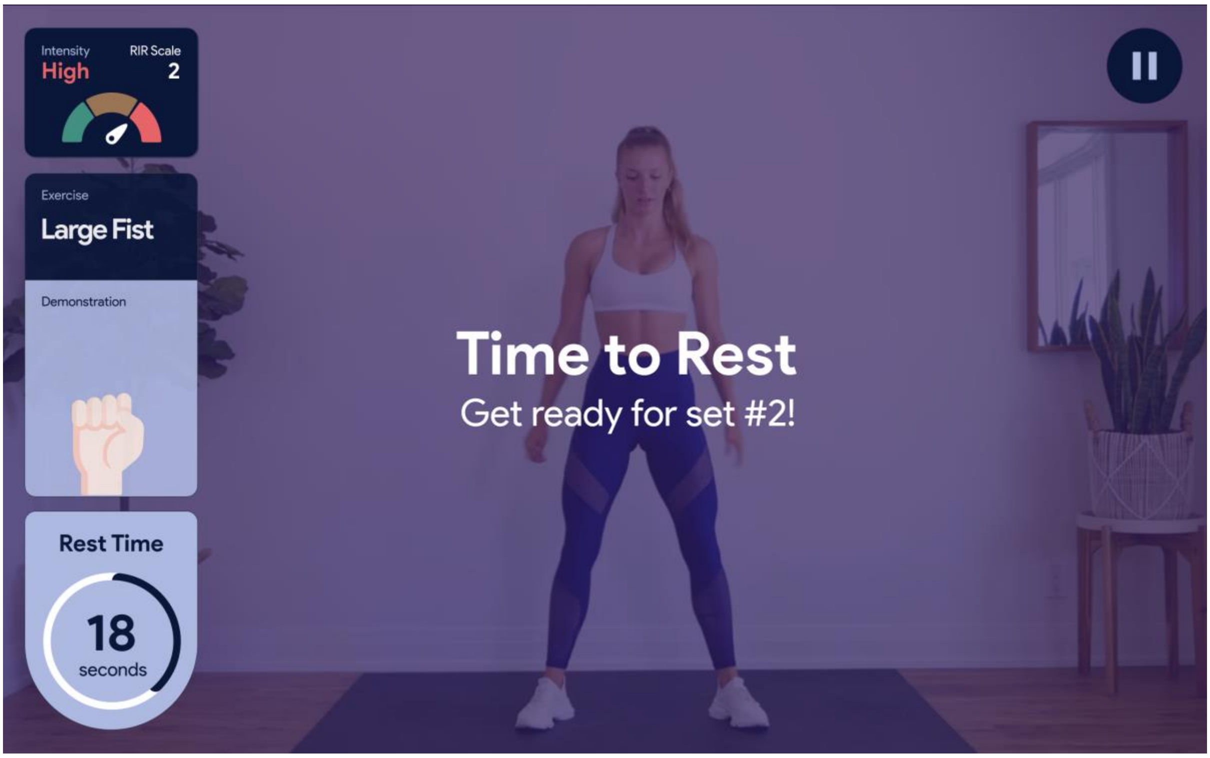



**Figure 70** Snapshot of the Rest Time screen in the "Spy" Exergame.

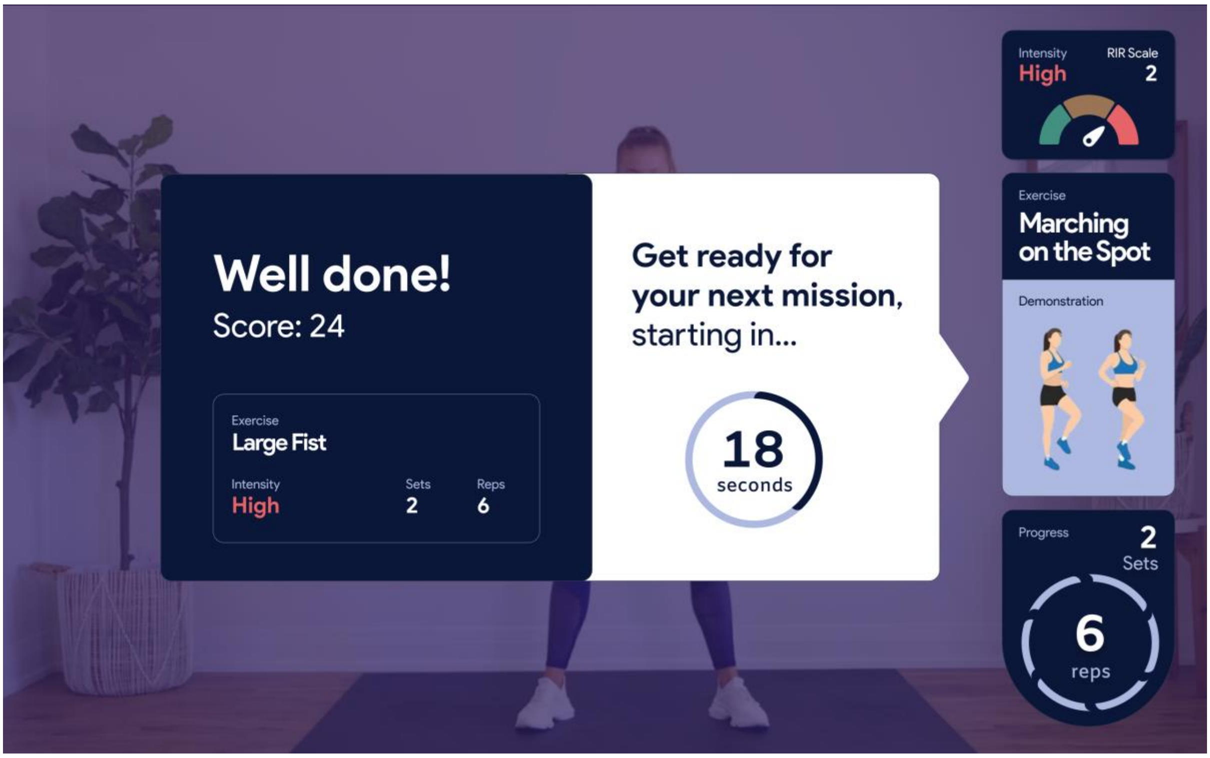



**Figure 71** Snapshot of the End-Game Results screen in the "Spy" Exergame.

## 3.3 Technical Information

### 3.3.1 Unity Integration with React Native

To integrate the Unity games with the React Native app, a smooth connection was achieved using the react-native-unity library, which allows Unity games to be embedded and launched within a React Native application. The process began by exporting the Unity project to Android, the current target platform, due to the lack of iOS development resources. React Native CLI was chosen over Expo for its access to internal files, enabling modifications to key files like build.gradle[44] and the App Manifest[45] to ensure communication between the app and the Unity project.

Challenges arose during integration. Unity's internal Android compiling tools (SDK[46]) caused permission issues, resolved by copying and authorizing their use in the app project. Conflicts between Unity versions further complicated the process, requiring an upgrade from Unity Editor Version 2021.3.30f1 to 2022.3.14f1 to ensure compatibility with the React Native Unity library. Additionally, Unity's default inclusion of the *Mobilenotifications* Android library caused errors, which were resolved by removing the library as it was unnecessary for the app.

Initially, the app was intended to host all games separately. However, limitations with the library, including the lack of support for hosting multiple Unity projects, led to the decision to have Unity host all games within a single project. With these adjustments, the Unity games are now fully playable within the React Native app.

### 3.3.2 FR, NFR and UR checklist

This section presents a checklist of FRs, NFRs and URs for the iPROLEPSIS Games application (as defined in D4.1 and D2.1), indicating which are covered by the current version of the application along with a plan for the rest (see **Table 1**-**Table 3**). Four additional URs have been included specifically for the game adaptation algorithm (UR.SG.11-NEW to UR.SG.14-NEW), aligning with the core principles of Trustworthy AI[47].

**Table 1** List of FRs for iPROLEPSIS Games application and current status.

| ID | Functional Requirement | Description | Implementation Status[48] | Justification |
|---|---|---|---|---|
| IP-25 | User authentication /login | The Serious Games Suite **must** allow patients to sign in using their iPROLEPSIS credentials (ID and password). | Achieved | - |
| IP-26 | Game selection | The Serious Games Suite **should** include a variety of games targeting different health aspects. | Achieved | - |
| IP-27 | Game levels | The Serious Games Suite **should** offer personalized game scenarios and adapt gameplay and levels of difficulty based on individual patient profile and goals. | Partially Achieved | Fixed difficulty levels have been implemented for the existing games. However, the development of an |

44 https://gradle.org/
45 https://developer.android.com/guide/topics/manifest/manifest-intro
46 https://developer.android.com/tools/releases/platform-tools
47 https://digital-strategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai
48 Comparing the final version of the iPROLEPSIS Games app (D4.7 “The iPROLEPSIS Serious Gaming Suite (MVP Version)” (M34)) with the current version of the application.

| | | | | |
|---|---|---|---|---|
| | | | | adaptation algorithm is intended to be created to dynamically personalize gameplay. This is planned for a later phase of the project. |
| IP-28 | Gameplay interaction | The games included in the Serious Games suite **should** allow active user participation through physical movements, gestures, or other inputs. | Partially achieved | Current games allow interaction through breathing inputs and fine motor skills, with plans to expand modalities for broader patient support. |
| IP-29 | Progress tracking | The Serious Games Suite **should** track and record patient progress within the games for evaluation and analysis. | Not Achieved | Prototypes for progress tracking have been developed, but full implementation is pending. |
| IP-30 | Gameplay feedback | The Serious Games Suite **must** provide feedback to patients based on their gameplay performance. | Partially Achieved | Feedback such as in-game scores and breathing performance is fully implemented, with plans to expand for more detailed and personalized insights (e.g. stress levels, pressure, average duration of hand movements). |
| IP-31 | Data synchronization | The games **could** be accessible on various devices such as smartphones, tablets, and PCs. | Partially Achieved | Compatibility testing has been successfully conducted on Android smartphones and tablets. |
| IP-32 | Multi-platform | Patient progress and preferences **could** be synchronized across devices to ensure a seamless gaming experience. | Partially Achieved | Initial synchronization capabilities have been tested on Android devices. Further development is needed to enable robust cross-device synchronization. |
| IP-33 | Clinician interaction | The system **could** allow clinicians to monitor patient progress, provide recommendations, and adjust game interventions if needed. | Not Achieved | Prototype features for clinician interaction have been conceptualized but not yet implemented. |

| | | | | |
|---|---|---|---|---|
| IP-34 | Game updates | The Serious Games Suite **could** support regular updates, to add new features, and improvements to the suite. | Partially Achieved | Periodic updates have been implemented based on feedback from co-creation sessions and internal technical evaluations. Continued updates are planned to introduce new features and refine existing functionalities, ensuring the system remains responsive to user needs. |

**Table 2** List of NFRs for iPROLEPSIS Games application and current status.

| Category Code | Non-Functional Requirement | Implementation Status | Justification |
|---|---|---|---|
| NFR_COMP | The Serious Games Suite **should** be compatible with various devices, such as smartphones, tablets, and motion-sensing devices, to accommodate different user preferences and capabilities. | Partially Achieved | Compatibility across smartphones and tablets has been tested and implemented, but integration with some motion-sensing devices is still under development. |
| NFR_MAIN | The code and software components of the Serious Games Suite **should** be documented and organized to facilitate updates, bug fixes, and maintenance. | Partially Achieved | The initial structure and documentation are in place for easy maintenance and updates. |
| NFR_PER | The games and interactive activities within the suite **should** smoothly respond to user inputs, providing a seamless and immersive experience. | Partially Achieved | The current games respond well to basic inputs; further improvements in responsiveness and fluidity are exploited. |
| NFR_PER | The suite **should** have minimal loading times and efficient resource management to minimize delays and optimize the overall performance. | Achieved | Performance optimization has been implemented for the games developed so far, ensuring fast loading times and efficient resource usage. |
| NFR_PORT | The Serious Games Suite **should** be designed to be portable across different devices (such as smartphones and tablets), allowing users to seamlessly switch between devices without losing progress or data. | Partially Achieved | The games can be accessed on multiple devices, but progress synchronization between them is still in progress. |

| | | | |
|---|---|---|---|
| NFR_PORT | The Serious Games Suite **should** support cloud-based storage and synchronization, enabling users to access their data and progress from different devices. | Not Achieved | Further development is required to ensure that data synchronization between devices is consistent and reliable across all platforms. This is planned for a later phase of the project. |
| NFR_REL | The Serious Games Suite **must** be stable, with minimal crashes or technical issues during gameplay. | Achieved | Stability has been tested, and the games are performing reliably with minimal crashes. Regular monitoring and updates confirm continued stability during gameplay. |
| NFR_SEC | The Serious Games Suite **must** comply with relevant data protection regulations and guidelines to ensure the safe handling and privacy of user data. | Not Achieved | This is planned for a later phase of the project. |
| NFR_UI | The UI of the Serious Games Suite **should** be intuitive, user-friendly, and accessible. | Achieved | - |
| NFR_UI | Clear instructions, visual cues, and feedback **should** be provided to guide users through the games and assist in achieving the intended wellness goals. | Achieved | - |
| NFR_COMP | The Serious Games Suite **should** be compatible with various devices, such as smartphones, tablets, and motion-sensing devices, to accommodate different user preferences and capabilities. | Partially Achieved | The suite is compatible with smartphones and tablets (Android). Future plans include expanding compatibility with motion-sensing devices. |

**Table 3** List of NFRs for iPROLEPSIS Games application and current status.

| UR.mP.# | Description | Implementation Status | Justification |
|---|---|---|---|
| UR.SG.01 | A patient **must** be able to register and sign in by creating an account and register within the Serious Gaming Suite. (User registration/sign in) | Achieved | This is fully implemented for tester accounts. |
| UR.SG.02 | A patient **should** be able to choose from a variety of games targeting different health aspects. (Game selection) | Partially Achieved | The system provides a selection of games, but further refinement is needed to offer the remaining game categories. |
| UR.SG.03 | A patient **should** be able to actively participate in the games through physical movements, | Partially achieved | Active participation is supported via breathing input and fine motor skills, but more |

| UR.mP.# | Description | Implementation Status | Justification |
|---|---|---|---|
| | gestures, or other inputs. (Gameplay interaction) | | interactive modalities (e.g., full-body gestures) are planned. |
| UR.SG.04 | The system **must** provide feedback to patients based on their gameplay performance. (Gameplay feedback) | Partially Achieved | Feedback on game scores and breathing performance is implemented, but additional personalized insights (e.g., stress levels, fine motor skills) are being developed. |
| UR.SG.05 | The system **should** track and record patient progress within the games for evaluation and analysis. (Progress Tracking) | Not Achieved | Prototypes for tracking have been developed, but full implementation is still pending. |
| UR.SG.06 | The system **should** offer personalized game scenarios and adapt gameplay and levels of difficulty based on individual patient profile and goals. (Personalization and adaptation) | Partially Achieved | Difficulty levels are personalized, but the full dynamic adaptation system, including long-term engagement features, is still in the exploratory development phase. |
| UR.SG.07 | The games **could** be accessible on various devices such as smartphones, tablets, and PCs. (Multi-platform support) | Partially Achieved | Games have been tested on smartphones and tablets, but further platform optimization is needed. |
| UR.SG.08 | Patient progress and preferences **could** be synchronized across devices to ensure a seamless gaming experience. (Data synchronization) | Not Achieved | This is planned for a later phase of the project. |
| UR.SG.09 | The system **could** allow clinicians to monitor patient progress, provide recommendations, and adjust game interventions if needed. (Clinician interaction) | Not Achieved | Some prototypes for clinician interaction have been developed but are not yet implemented. This feature is planned for later phases. |
| UR.SG.10 | The system **could** support regular updates, to add new features, and improvements to the suite. (Game updates) | Achieved | Regular updates are being made based on user feedback and technical improvements, ensuring continuous enhancement of the application. |
| UR.SG.11-**NEW** | The system should provide patients with clear explanations of how AI-adaptive algorithms influence game scenarios, difficulty levels, and personalized recommendations. (Transparency and Explainability) | Not achieved | This is planned for a later phase of the project. |

| UR.mP.# | Description | Implementation Status | Justification |
|---|---|---|---|
| UR.SG.12-**NEW** | The AI adaptation algorithm must ensure equitable access to game benefits across diverse patient profiles, avoiding biases related to age, gender, ethnicity, or physical ability. (Fairness) | Not achieved | This is planned for a later phase of the project. |
| UR.SG.13-**NEW** | The system must implement privacy-preserving techniques in AI algorithms, ensuring that patient data used for personalization is anonymized and securely processed. (Privacy and data protection) | Not achieved | This is planned for a later phase of the project. |
| UR.SG.14-**NEW** | The AI adaptation algorithm should undergo regular evaluations to identify and mitigate biases, improve personalization, and ensure alignment with evolving health guidelines. (continuous improvement) | Not achieved | This is planned for a later phase of the project. |

# 4 Future developments and next steps

## 4.1 Feedback incorporation and iterations

In parallel with developing and implementing the remaining games, the next steps involve preparing and organizing the fifth Co-creation session, scheduled for February 2025. This session will primarily focus on presenting the “Escape” Exergame, and potentially the “Spy” Exergame, to receive valuable feedback from patients, clinical experts, and technical specialists. The feedback gathered during this session will be important in refining the proposed games and enhancing specific features. The insights will help identify areas for improvement, fine-tune gameplay mechanics, and ensure the games meet the needs and expectations of both patients and healthcare professionals. This iterative process will contribute to the continuous development and optimization of the games, with the ultimate aim of improving user engagement and health outcomes.

## 4.2 Cloud-based data management system

The cloud-based Data Management System (DMS), developed in T4.5 “Data storage and analytics infrastructure setup and maintenance”, is a set of services that facilitate all digital data operations of the iPROLEPSIS applications. The development of the system follows an Agile methodology, with frequent intermediate versions regularly released throughout the project’s duration. The DMS includes the following sub-components, which are bundled and deployed as individual Docker Containers or as services on Linux OS virtual machines:

- User Authentication service
- HTTPS RESTful API, encompassing also the data quality checks mechanism
- Data Storage solution, including a NoSQL storage cluster and an Object storage space
- User Adherence Monitoring service
- Data Analytics Tools

**Figure 72** showcases the internal architecture of DMS with components being divided into three logical groups according to their purpose (i.e., User Management and Authentication, Data Analysis and Reporting, and Data Management and Storage).

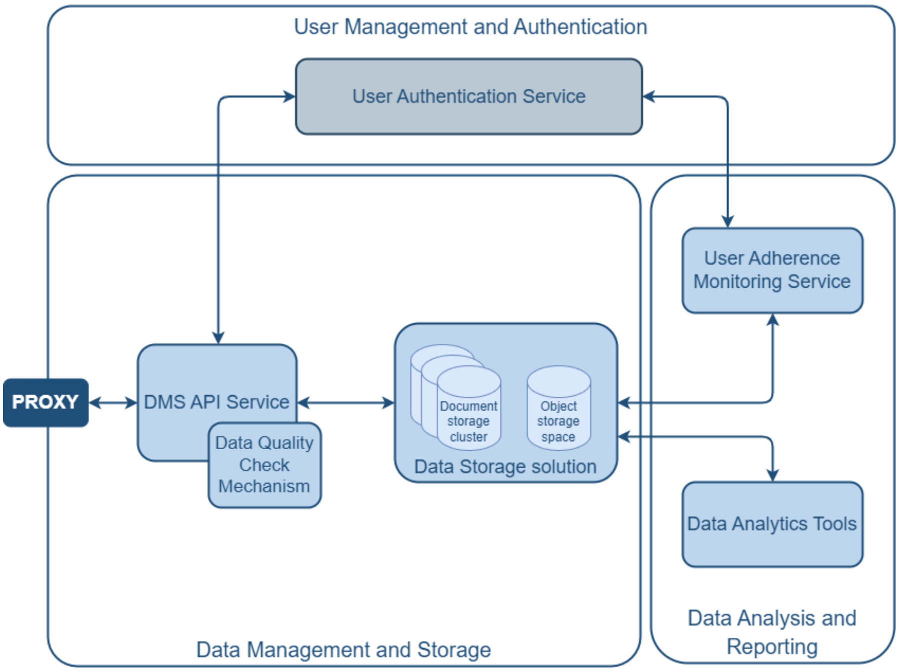



**Figure 72** Cloud-based DMS internal architecture diagram.

Further details can be found in the deliverable D4.1 "Initial technical specifications, architecture and product backlog*",* which provides a detailed presentation of the application design and technical specifications. Additionally, deliverable D4.2 "The iPROLEPSIS patient and HCP apps (study version)", thoroughly describes the setup, implementation and deployment of the cloud-based DMS.

In particular, to accommodate the iPROLEPSIS Serious Gaming Suite, ongoing efforts are being made to extend the implementation of DMS API Service. These extensions aim to provide the necessary endpoints for storing and retrieving data generated by the Serious Gaming platform, ensuring seamless integration with the existing DMS system (see **Figure 73**).

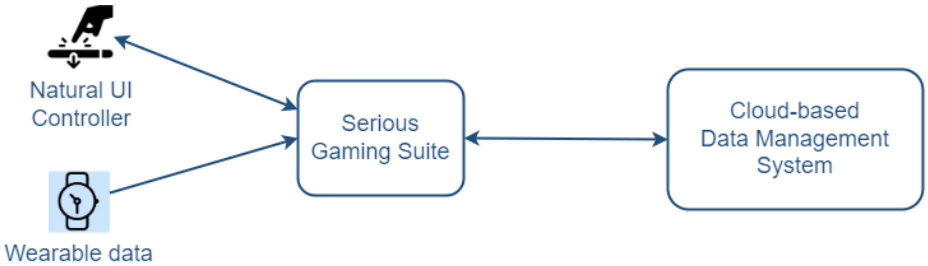



**Figure 73** Serious Gaming Suite and Cloud-based DMS high-level interaction diagram.

Additionally, the Serious Gaming Suite utilizes the User Authentication Service, an instance of the Keycloak Identity and Access Management (IAM) solution for user authentication, ensuring secure and seamless access to the DMS. The Keycloak service, set up and managed by INTRA in collaboration with AUTH as the infrastructure provider, implements the OAuth 2.0 protocol to enable secure Single Sign-On (SSO) functionality across the iPROLEPSIS ecosystem components.

To support integration with the Serious Gaming Suite, the relevant client configuration was created and provided by INTRA. This configuration allows the gaming platform to interact with Keycloak, enabling it to authenticate users and manage sessions securely. Through this setup, players can log in and access the suite's functionalities while ensuring that authentication adheres to the established security standards of the iPROLEPSIS ecosystem.

## 4.3 Adaptation algorithm

In order to enable the creation of the Personalized Game Suite, we propose the development of an algorithm to adapt the games within the suite to the patient's capabilities[49]. Although the idea is still at an early stage, we aim to use data observed from the patient's in-game interaction, e.g., gameplay metrics and physiological readings, to inform an algorithm for Dynamic Difficulty Adjustment (DDA)[50]. The data used as DDA input may include the time taken to complete tasks, success/failure rates, and movement precision or range. This may be coupled with physiological data such as heart rate, stress levels, or breathing information. Throughout gameplay, patterns in these measurements should help the DDA method to model patient progress, i.e., the data from each gameplay segment should help infer whether the patient's condition improved, worsened, or stabilized. Additionally, the DDA algorithm should be able to incorporate feedback from patients or clinicians to further adjust its execution.

[49] Tadayon, R., Sakoda, W., & Kurita, Y. (2020). Stealth-adaptive exergame design framework for elderly and rehabilitative users. In *Human Aspects of IT for the Aged Population. Healthy and Active Aging: 6th International Conference, ITAP 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings, Part II 22* (pp. 419-434). Springer International Publishing.
[50] Lopes, J. C., & Lopes, R. P. (2022, October). A review of dynamic difficulty adjustment methods for serious games. In *International Conference on Optimization, Learning Algorithms and Applications* (pp. 144-159). Cham: Springer International Publishing.

After a patient’s condition is inferred, it can directly inform certain gameplay tweaks specific to each game task in a way that improves patient's condition[51]. Gameplay adjustments include the number of task repetitions, task duration, or in-game reward attribution.

**Figure 74** depicts a possible high-level architecture for the proposed DDA system. In this architecture, data are drawn from two primary sources: a training database, and real-time interaction between the patient and the game. The training database includes historical data, including gameplay metrics and physiological readings from a broad population, which helps establish baseline patterns and relationships. This pre-existing data enables the AI module to undergo initial training, equipping it with the ability to model and interpret diverse patient conditions, effectively. Once the system is trained, real-time data from the patient’s interactions with the game, such as task completion times, success rates, movement precision, and physiological responses like heart rate or stress levels, is continuously fed into the AI module. This input allows the module to evaluate the current state of the patient accurately.

Based on the patient’s condition inferred by the AI module, the system adjusts gameplay parameters dynamically. This feedback loop ensures the game remains engaging, effective, and aligned with the patient's progress.

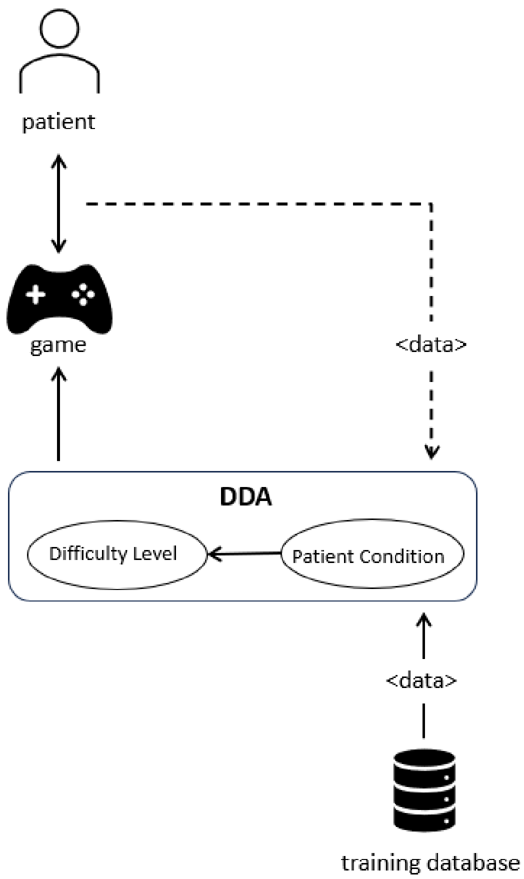



**Figure 74** High-level architecture for the proposed DDA system.

[51] Sutton, R. S. (2018). Reinforcement learning: An introduction. *A Bradford Book*.

# 5 Conclusions

This report outlines the progress and ongoing developments of the iPROLEPSIS Games app. The iPROLEPSIS Games app includes six distinct categories: Breathing Games, Exergames, Sensorimotor Art, Emotional, Dietary, and No-Pain Games, with **four serious games implemented** to date: The Kite, Star Catcher, Mr. Blue Sky, and Escape. Each game incorporates 6 to 10 menus, covering key functionalities such as loading screens, main menus, difficulty selection, calibration (specific to Breathing Games), practice modes, tutorials, and endgame menus. These features allow users to track their progress, with the endgame menus displaying performance scores and stats, as well as offering replay options. Additionally, a link system in each game category connects to relevant research papers, adding an educational layer to the app.

The design of the iPROLEPSIS Games app, referred to as the iPROLEPSIS Games World, places a strong emphasis on user-centric navigation. It features intuitive entry points and clear reference material to guide users through each game. This thoughtful design ensures that players can easily navigate the app and engage with its features, enhancing the overall user experience. The app’s layout and functionality have been carefully created to be accessible and user-friendly, providing players with a smooth journey through its various game categories. Furthermore, so far, **33 original 3D models** have been created to enhance the visual experience and facilitate easy navigation. Adaptability is another key feature of the app, with games offering calibration and adjustable difficulty settings to accommodate different health conditions. Endgame menus provide valuable feedback, including scores and stress levels, helping users monitor their progress.

Looking forward, the iPROLEPSIS Games app is set to expand with additional categories, including Sensorimotor Art, Emotional, Dietary, and No-Pain Games, which will be integrated into the existing framework. This expansion will further broaden the iPROLEPSIS Games app's capabilities and enhance its functionality.

Future development will focus on generating new versions of the iPROLEPSIS Games app, incorporating additional personalization features, optimizations, and bug fixes. Further phases of the development will include the creation of a Minimum Viable Product (MVP) for the Serious Games Suite, which will integrate personalized gameplay based on each player’s profile and will be released in Deliverable D4.7 (M34).

# References

Abd-Alrazaq A, Abuelezz I, Al-Jafar E, et al. The performance of serious games for enhancing attention in cognitively impaired older adults. npj Digit Med 2023;6:122.

Argenton L, Pallavicini F, Mantovani F. Serious games as positive technologies. In: Cruz-Cunha MM, Reis LP, Martinho R, eds. Handbook of research on applied e-learning in engineering and architecture education. Hershey, PA: IGI Global, 2016:114-32.

Azeem, M. F. (Ed.). (2012). Fuzzy inference system: theory and applications. BoD–Books on Demand.

Caserman P, Hoffmann K, Muller P, et al. Quality criteria for serious games: serious part, game part, and balance. JMIR Serious Games 2020;8:e19037.

Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q 1989;13:319-340.

Dias, S. B., Diniz, J. A., Konstantinidis, E., Savvidis, T., Zilidou, V., Bamidis, P. D., ... & Hadjileontiadis, L. J. (2021). Assistive HCI-serious games co-design insights: the case study of i-PROGNOSIS personalized game suite for Parkinson’s disease. Frontiers in Psychology, 11, 612835.

Dias, S. et al. (2020). Smartphone-based biofeedback games for shielding of immune system against COVID-19: the Covidshield game suite design approach. In Proceedings of the 9th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion (pp. 93-97).

Gottesdiener, E., 2010. The 4L’s: A Retrospective Technique. Online. Last accessed on (November 24, 2024). https://www.ebgconsulting.com/blog/the-4ls-a-retrospective-technique/.

Knapp, J., Zeratsky, J., & Kowitz, B. (2016). Sprint: How to solve big problems and test new ideas in just five days. Simon and Schuster.

Koffka, K. (2013), Principles Of Gestalt Psychology, International Library of Psychology, Taylor & Francis. URL: https://books.google.ae/books?id=tWxHAQAAQBAJ

Lopes, J. C., & Lopes, R. P. (2022, October). A review of dynamic difficulty adjustment methods for serious games. In International Conference on Optimization, Learning Algorithms and Applications (pp. 144-159). Cham: Springer International Publishing.

Palumbo, R. (2017). The bright side and the dark side of patient empowerment: Co-creation and co-destruction of value in the healthcare environment. Springer.

Pouls BP, Bekker CL, Gundogan F, et al. Gaming for adherence to medication using ehealth in rheumatoid arthritis (GAMER) study: a randomised controlled trial. RMD Open 2022;8:e002616.

Sarstedt M, Ringle MC, Hair JF. Partial least squares structural equation modeling. In: Homburg C, Klarmann M, Vomberg A, eds. Handbook of market research. Cham: Springer International Publishing, 2021:587-632.

Sigailov-Lanfranchi, J. (2019). Impact of Different Levels of Difficulty on Immersion in Video Games. In AICS (pp. 248-259).

Sutton, R. S. (2018). Reinforcement learning: An introduction. A Bradford Book.

Tadayon, R., Sakoda, W., & Kurita, Y. (2020). Stealth-adaptive exergame design framework for elderly and rehabilitative users. In Human Aspects of IT for the Aged Population. Healthy and Active Aging: 6th International Conference, ITAP 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings, Part II 22 (pp. 419-434). Springer International Publishing.

Tessarolo, F., Petsani, D., Conotter, V., Nollo, G., Conti, G., Nikolaidou, M., ... & Konstantinidis, E. I. (2024). Developing ambient assisted living technologies exploiting potential of user-centred co-creation and agile methodology: The CAPTAIN project experience. Journal of Ambient Intelligence and Humanized Computing, 15(5), 2661-2676.

# Appendixes

## Appendix 1. Storyboards

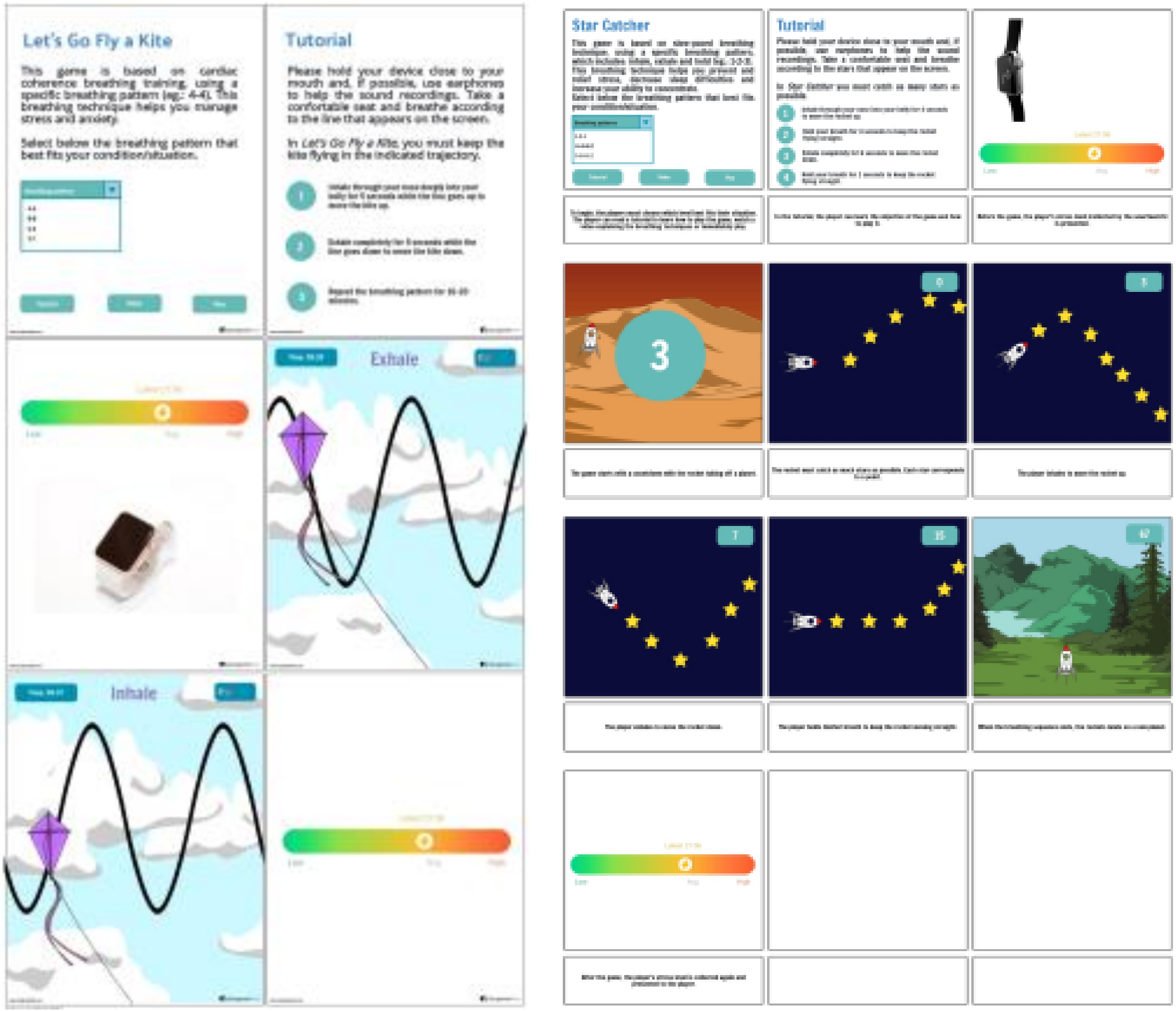


**Figure S1** Storyboards for the Breathing Games: “The Kite” game (left) and “The Star Catcher” (right).

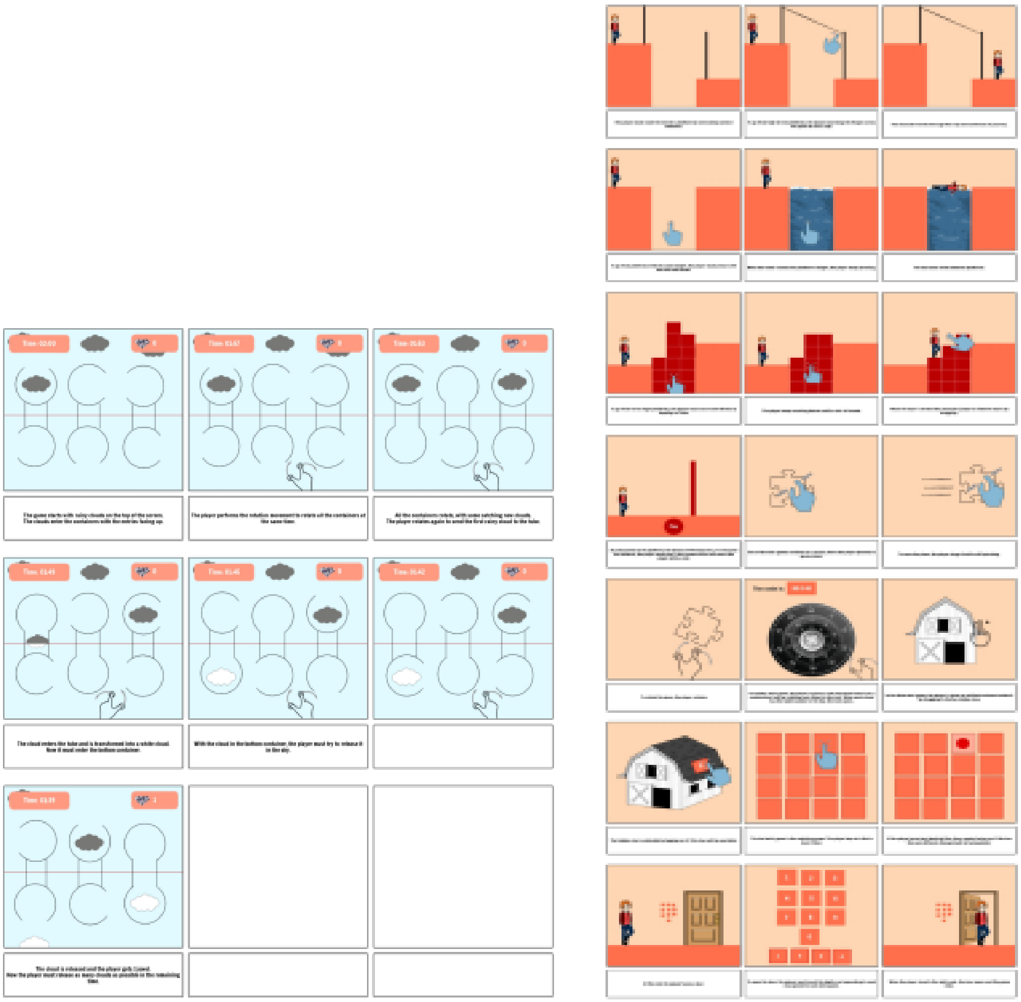


**Figure S2** Storyboards for the fine motor skills Exergames: "The Blue Sky" game (left) and "Escape" (right).

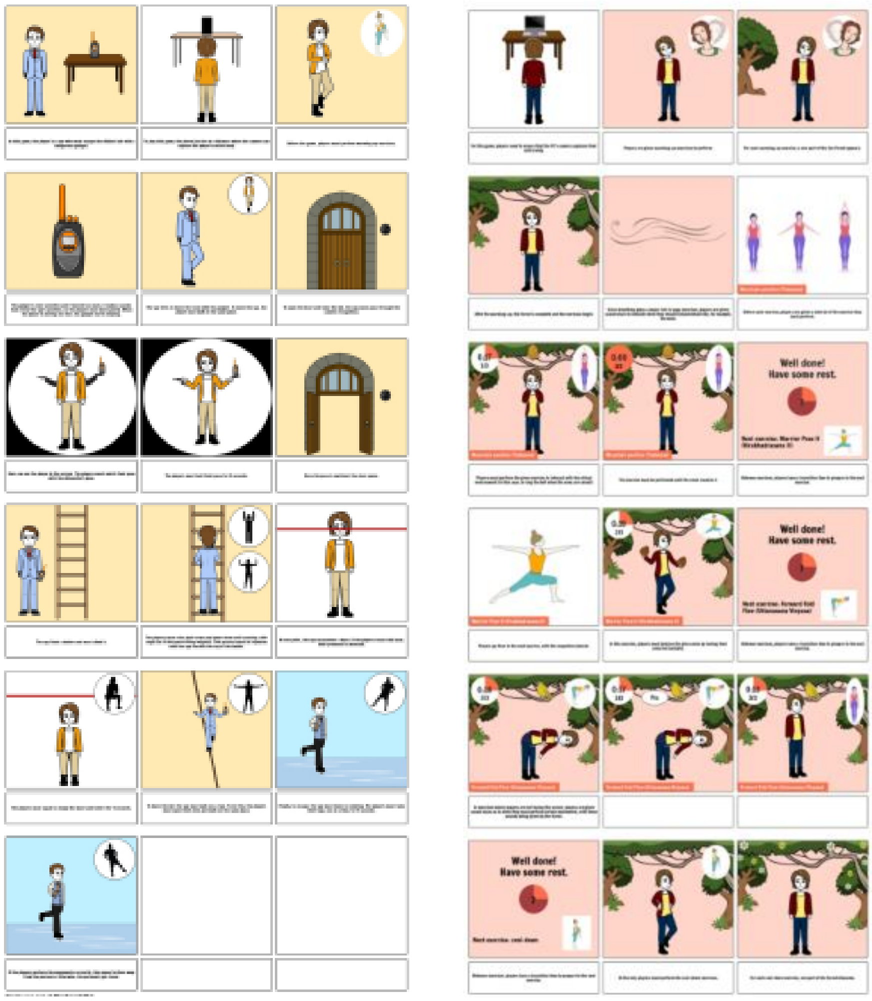



**Figure S3** Storyboards for the full body Exergames: “The Spy” game (left) and “The Zen Forest” (right).

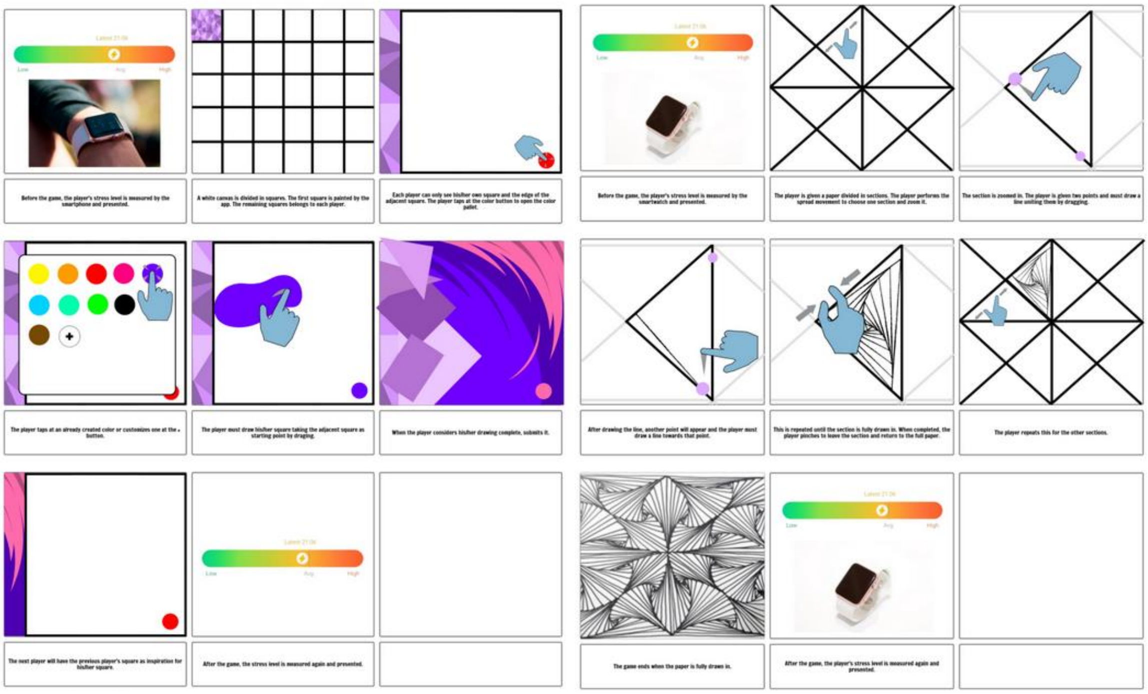


**Figure S4** Storyboards for the Sensorimotor Games: “One art” game (left) and “Illusion Doodle” (right).

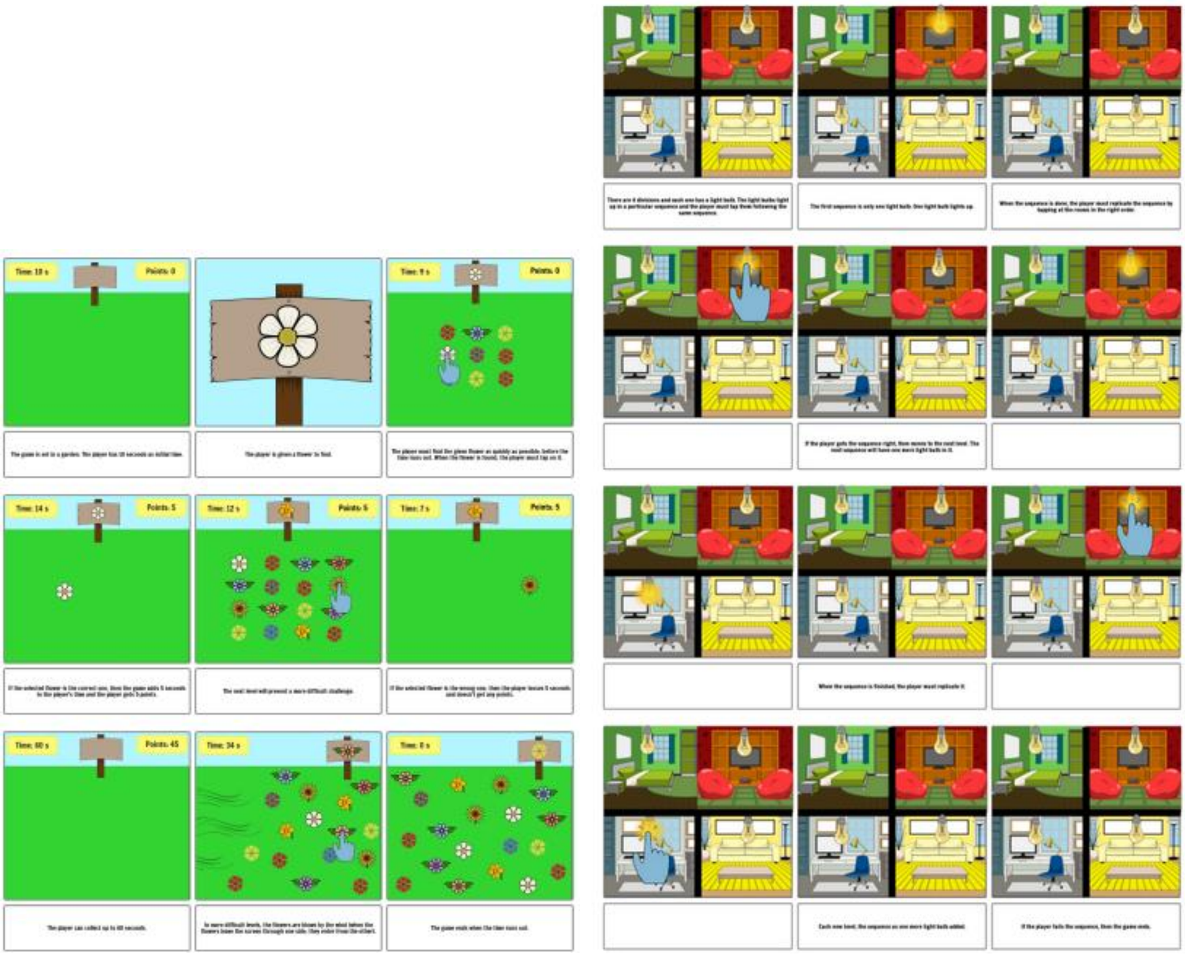


**Figure S5** Storyboards for the NoPain Games: “The Gardner” game (left) and “Lightning” (right).

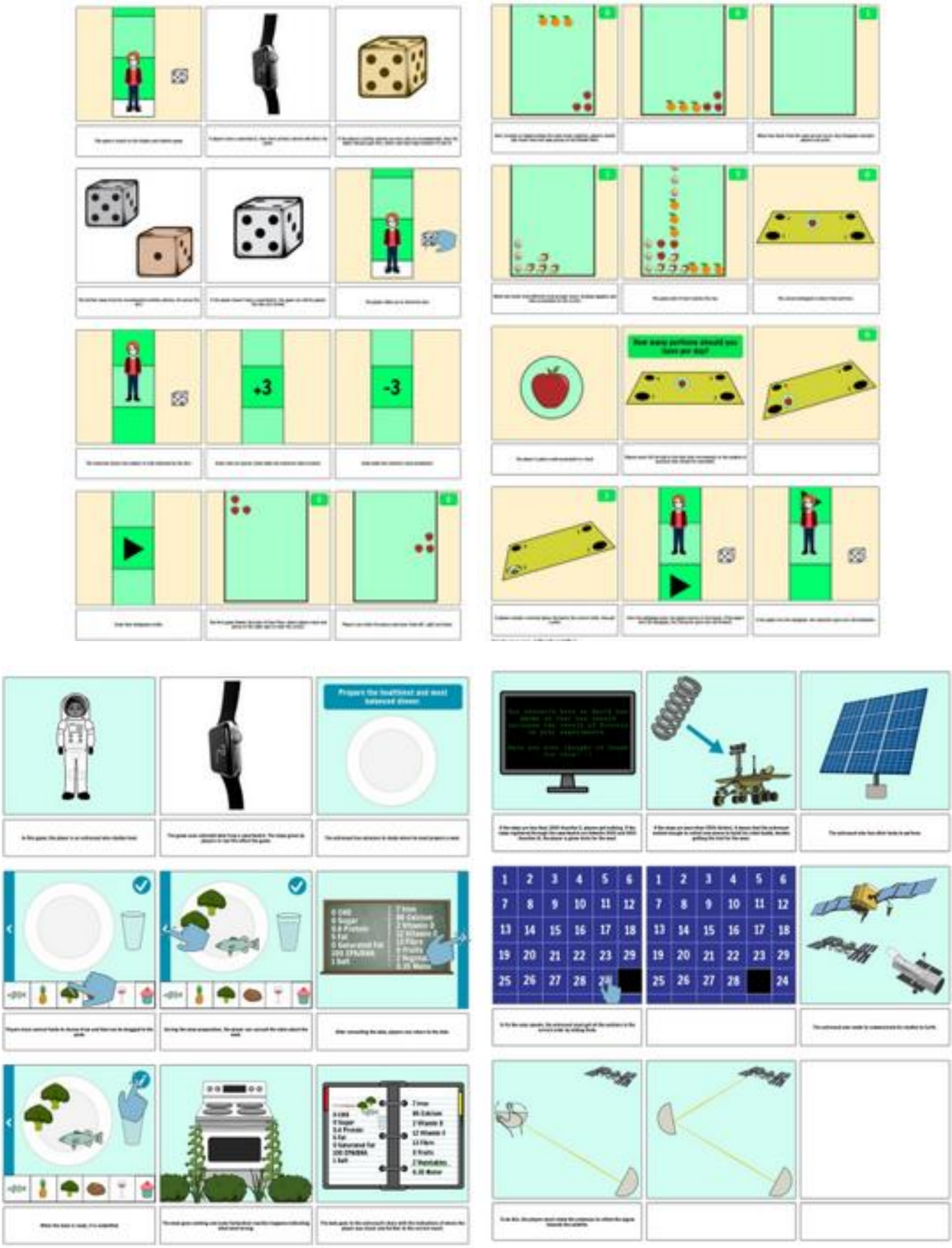



**Figure S6** Storyboards for the DietaryGames: “Up and down” game (top) and “The Food Scientist” (bottom).

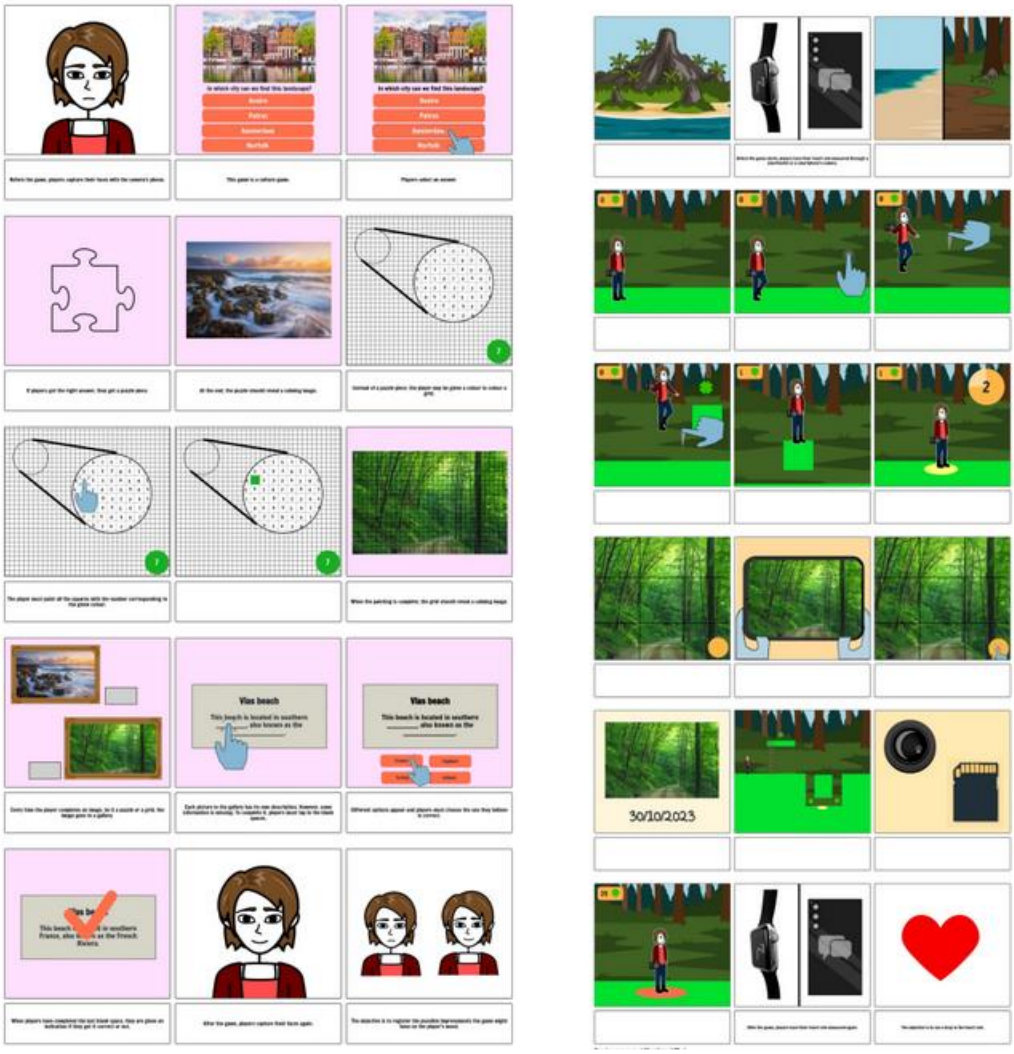
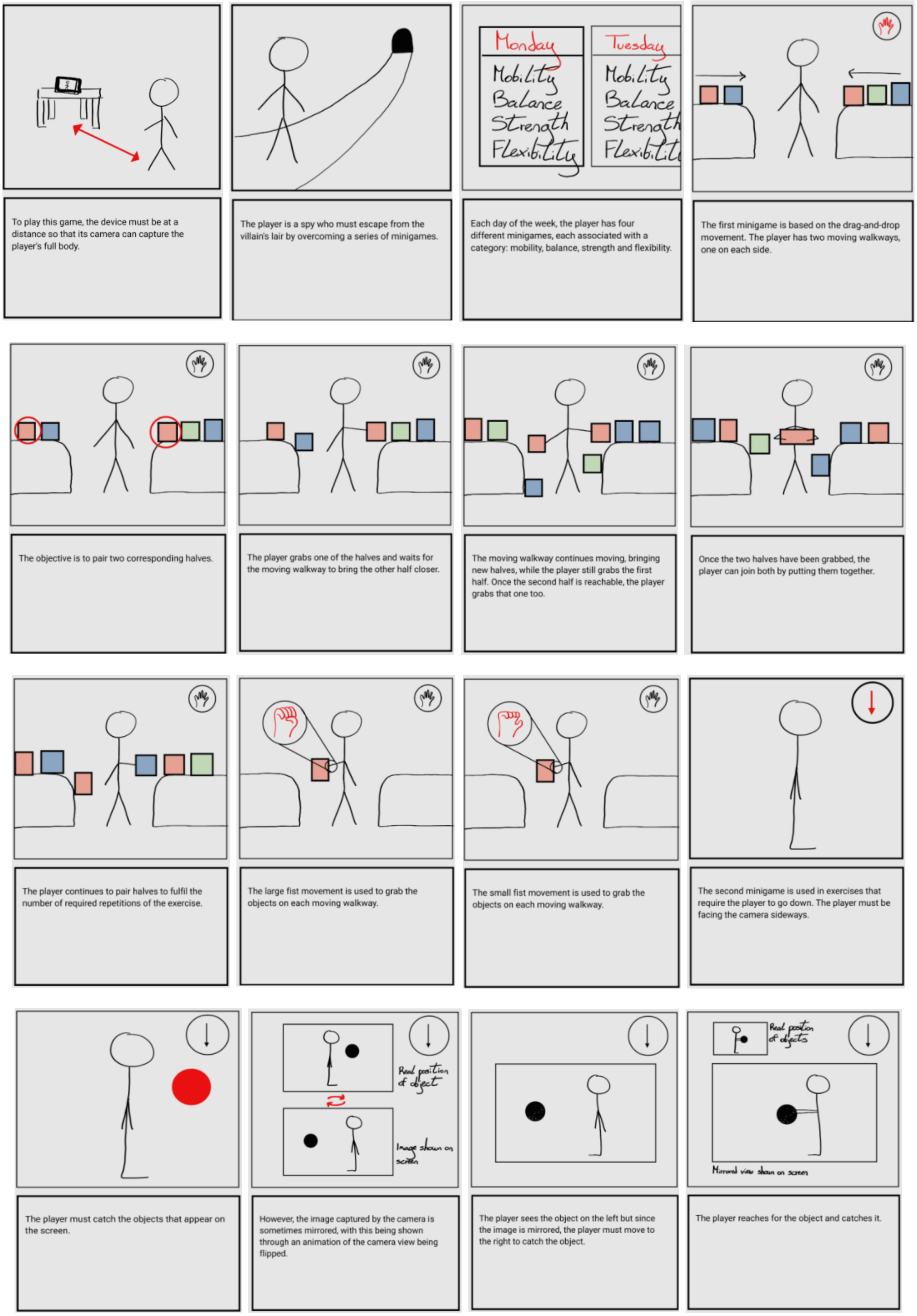
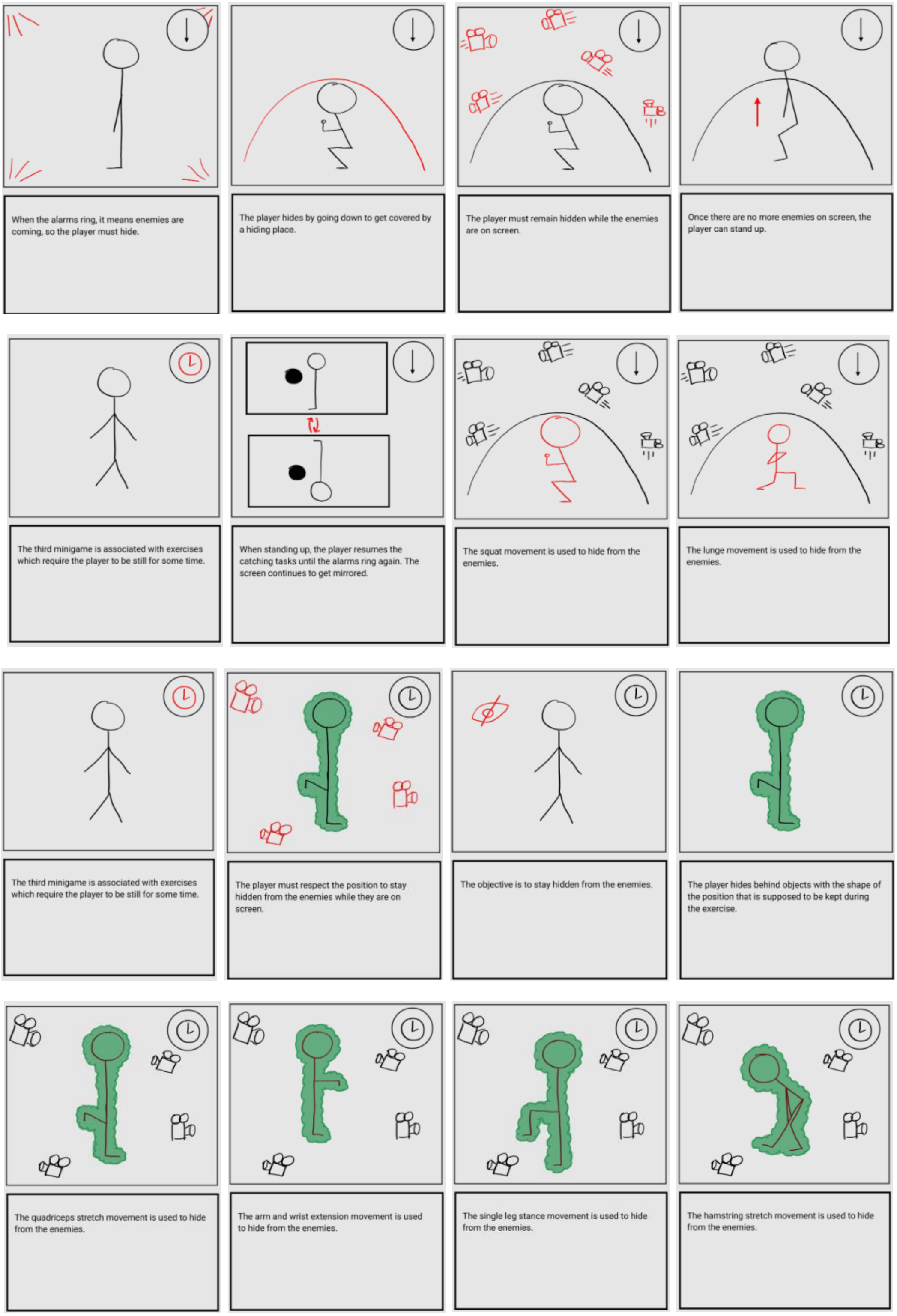
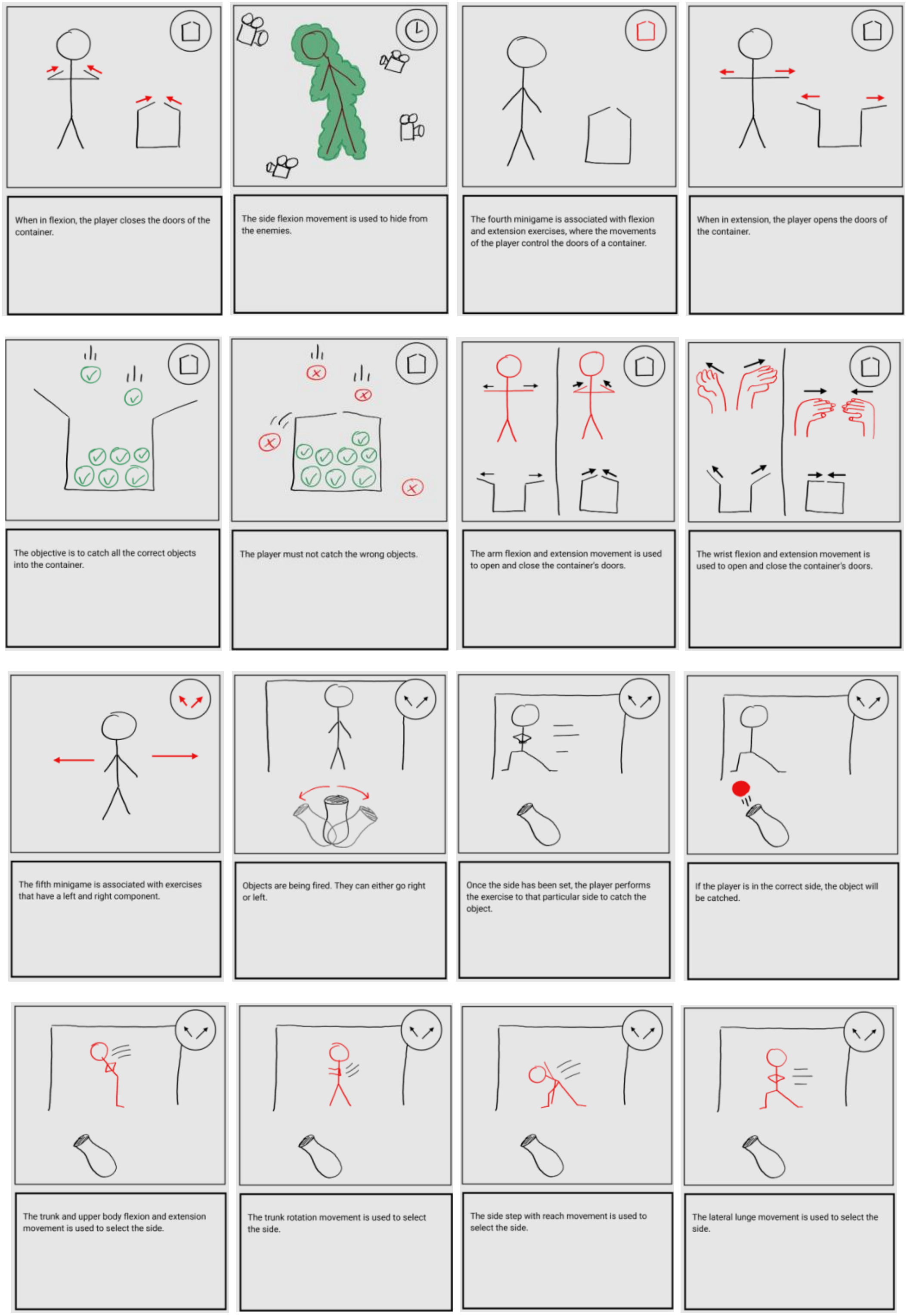



**Figure S7** Storyboards for the Emotional Games: “The Quiz” game (left) and “The Photographer” (right).

# Appendix 2. Updated Storyboard for the "Spy" exergame




When the alarms ring, it means enemies are coming, so the player must hide.
The player hides by going down to get covered by a hiding place.
The player must remain hidden while the enemies are on screen.
Once there are no more enemies on screen, the player can stand up.
The third minigame is associated with exercises which require the player to be still for some time.
When standing up, the player resumes the catching tasks until the alarms ring again. The screen continues to get mirrored.
The squat movement is used to hide from the enemies.
The lunge movement is used to hide from the enemies.
The third minigame is associated with exercises which require the player to be still for some time.
The player must respect the position to stay hidden from the enemies while they are on screen.
The objective is to stay hidden from the enemies.
The player hides behind objects with the shape of the position that is supposed to be kept during the exercise.
The quadriceps stretch movement is used to hide from the enemies.
The arm and wrist extension movement is used to hide from the enemies.
The single leg stance movement is used to hide from the enemies.
The hamstring stretch movement is used to hide from the enemies.


When in flexion, the player closes the doors of the container.
The side flexion movement is used to hide from the enemies.
The fourth minigame is associated with flexion and extension exercises, where the movements of the player control the doors of a container.
When in extension, the player opens the doors of the container.
The objective is to catch all the correct objects into the container.
The player must not catch the wrong objects.
The arm flexion and extension movement is used to open and close the container's doors.
The wrist flexion and extension movement is used to open and close the container's doors.
The fifth minigame is associated with exercises that have a left and right component.
Objects are being fired. They can either go right or left.
Once the side has been set, the player performs the exercise to that particular side to catch the object.
If the player is in the correct side, the object will be catched.
The trunk and upper body flexion and extension movement is used to select the side.
The trunk rotation movement is used to select the side.
The side step with reach movement is used to select the side.
The lateral lunge movement is used to select the side.

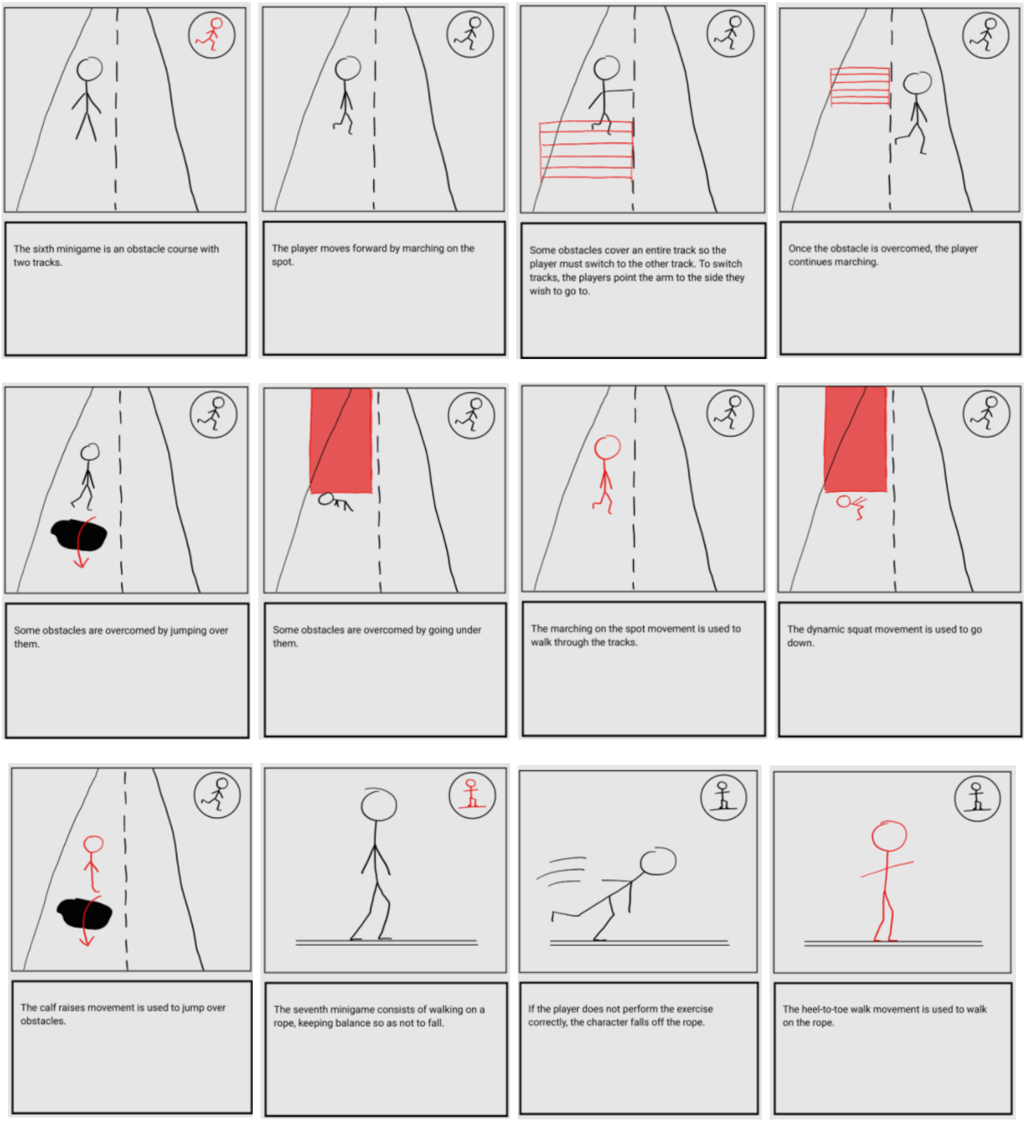



**Figure S8** Updated storyboards for the “Spy” exergame.