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PLAY - Model-based Platform to Support Therapeutic Serious Games Design

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Abstract

One of the reasons why patients lose focus and interest in physiotherapy exercises is their repetitive nature. Frequently used techniques when trying to promote user engagement and motivation are the gamification of tasks and use of serious games. This paper conceptualizes a framework model to support the design of serious games for children with special needs and a computational platform that implements this concept. The model includes the definition of games based on levels and sequences of actions. The actions model therapeutic exercises. The platform allows the creation of game actions applicable for specific therapies. The setting of the game action scope, in relation to the intended therapies, allows the system to suggest specific actions, based on the patient profile and current needs. The platform allows for later viewing and analysis of recorded results and a comparative analysis of patients' usage data and results is possible. Moreover, data and results can be shared and compared between clinics that use the platform.

Keywords: Serious Games; Children; Special Needs; Web-based Platform; Therapy; Model-driven Design.

1. Introduction

Patients with special needs (SN) present conditions that limit their skills, in some way, during some time. These conditions can be chronic and temporary [13]. Patients with SN can be recovering from temporary injuries like broken arms, episodic events like stroke, or dealing with chronic conditions like cerebral palsy (CP). Patients with this kind of impairments cannot usually use the generic e-health tools available and need specific solutions. Solutions designed for patients with SN must be adaptive by nature, allowing extra degrees of personalization, to be efficiently used by most patients [1], who often require interventions in multiple simultaneous therapy areas. Users with CP require SN [12] and

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most children with CP live with relevant motor and posture impairments. It is a chronic condition and physiotherapy is one of the main tools for motor function rehabilitation and cognitive stimulation. Children have distinct characteristics than adults [11]. There is a need for specific tools directed for children with CP. Tools addressing the main factors at stake (e.g., children, CP, therapy protocols, progression monitoring and analysis) are rare and expensive. One of the reasons for patients losing focus and interest in physiotherapy exercises is their repetitive nature. Having to perform the same exercise for a long time is tedious and tiresome for anyone, which is even more relevant when dealing with children and specifically children with SN.

A frequently used technique when trying to promote user engagement and motivation is the gamification of tasks [2]. Another way to motivate users is through the implementation of serious games (SG) [3]. SG are games where the main purpose is not entertainment. The game concept is used to integrate what would otherwise be a set of long and tedious exercises. Naturally, the game itself must be appealing, dynamic and progressive to capture the target audience's attention and keep that focus. Actuation devices are used as a mean for creating more immersive environments [4], providing other means of interaction with users, and promoting interest and motivation. Customization and personalization are also key factors when designing solutions for children with SN. Systems must adapt to multiple patients with multiple degrees of conditions. Even applications that focus on only one impairment must deal with the distinct and unique condition of each patient. Developing inclusive technology is needed for providing functionalities to users that cannot find answers on current solutions.

Motivation for this research is built on the mentioned factors. Moreover, the continuity and improvement of the line of research already pursued in previous work is needed since specific needs of therapists and patients have been identified during sessions and interviews at a stakeholder clinic. As contributions from this research a framework model was conceptualized and a computational platform was implemented. The model includes the definition of games based on levels and sequences of actions of therapeutic exercises. The platform implements the model and allows for particular games definition towards personalized therapies.

2. Related Work

Model-driven frameworks were proposed by Tang et al. [10], to support the design of educational SG allowing real time update of settings during exercise execution, and Khowaja et al. [11], for the design of vocabulary-based serious games with children with Autism Spectrum Disorder (ASD), using a conceptual model based on 3 interconnecting layers (theory, content, and game design) to develop a prototype SG with expert validation. Alcover et al. [5] propose the PROGame process framework for serious game development focused on motor rehabilitation, identifying desirable features for rehabilitation SG, and applying a methodology in the development of SG for improvement of balance and postural control of CP adult patients.

Hunicke et al. [14] developed the MDA model, a game design framework. The model has 3 layers: mechanics, dynamics, and aesthetics. All layers are interconnected and get input and output from each other. The Mechanics layer relates to game structural components (e.g. data model and algorithms), the Dynamics layer deals with game interaction (e.g. runtime behaviors for mechanics components), and the Aesthetics layer relates to game ambiance. The aesthetics components include sensation, fantasy, narrative, challenge, fellowship, discovery, expression, and submission. Distinct gameplays value some areas more than others, providing different experiences and searching for a specific emotional response from the user.

Omelina et al. [6] discuss a specialized configurable system architecture for games focusing on neuro-muscular rehabilitation. The solution aims at increasing the adaptability and usability of exergames both for patients and therapists and is based on three layers: a game controls layer for hardware abstraction, a game configuration layer for game variables controls and the game logic layer. A prototype with four mini games is presented, also providing tools for progression analysis.

Recommendation systems help the decision-making process, for instance, guiding therapists and patients to select the most adequate option for their goals, in the relevant context. A smart system using a recommendation system suggesting relevant rehabilitation exercises, based on user skills, was presented by González et al. [7]. The TANGO:H platform allows the design of accessible educational games using the Kinect sensor. The system provides personalized game modes based on the history and preferences of each user. A configurable level system allows more precise adaptation and personalization of exercises. The difficulty of exercises increases with user experience preventing exercises to become repetitive and boring.

3. Computational Framework

The development of SG is a complex task and its focus on children presents specific challenges, which makes the process differ from the one targeting older users. Children with SN have extra requirements and constraints that must be considered. The customization and personalization of solutions is very important.

The conceptual model for this framework is based on the notion that children requiring SN must perform physiotherapy exercises for rehabilitation and regain functionality. Due to the repetitive nature of the rehabilitation and the characteristics of the population, SG are used to motivate and promote engagement while exercising. The complexity and extreme variation of focused pathologies require flexibility and adaptation strategies from solutions. Data from user interactions must be collected and analyzed to be usable in decision-making processes. Therapists and patients can benefit from that acquired knowledge. The framework model (Fig. 1) is composed by 3 interconnected layers:

- The domain layer relates to the child patients and their needs, the therapies, and results analysis.
- The technology layer includes software and hardware solutions.
- The game layer relates to game design and SG elements.

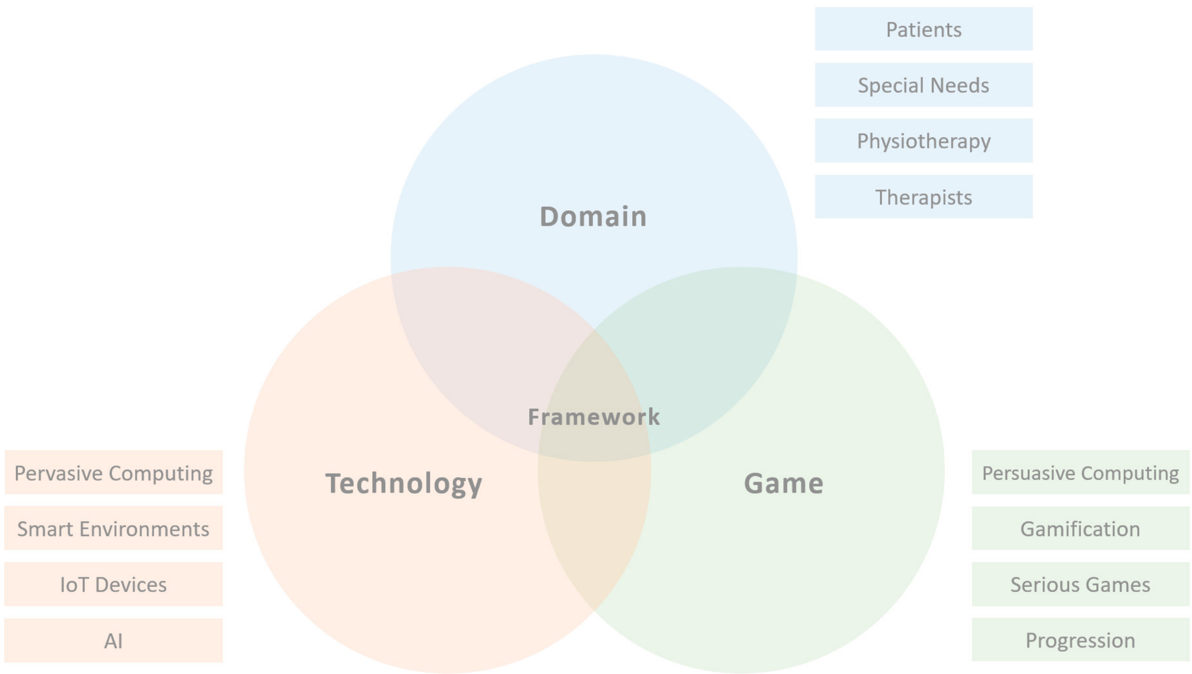

Fig. 1. Framework model

The intersection of the layers provides the methodologies and tools for this framework including game performance and profile progression analysis, by therapists and machine learning (ML) tools, producing knowledge. The framework model is based on a set of premises. Patients have therapeutic needs and require physiotherapy services. Physiotherapy sessions often require repetitive exercises. Serious games are used to promote engagement and motivation. A platform for assisting therapists implementing physiotherapy protocols using serious games is provided. The platform allows management of users and SG therapy sessions. Users can have roles of patient, therapist, clinic, or administrator. Patients have a therapeutic profile. The patient profile is based on personal info, usage history, therapist analysis, and results. Therapists configure games, composed of sequences of actions organized in levels. Actions have parameters, defining their runtime behavior, and relate to sensor devices. Therapists schedule game executions in patients' exercise schedules. Games are recommended based on the patient profile. Patients play games. Games can be platform or external games. Games use local sensor and actuator devices, and send results and samples to server. Therapists can monitor the game flow and adjust game parameters in real time. The framework model integrates the components of each layer, allowing several advantages, and providing:

- Model for patient profile and flexible model for games.
- A recommendation system for games based on the user profile.
- Repository of game executions, results, and samples.
- Data source for ML algorithms and other tools for obtaining knowledge.
- Abstraction of devices and easy access to data and tools using the Internet.

A model-driven approach when building SG has several benefits including efficiency and validation of models. The abstraction of the technology behind concepts allows design of more intuitive tools for domain experts.

4. The PLAY Platform

PLAY is a multiuser web-based platform for patients, therapists, and clinics, providing tools for the several roles, allowing data analysis on those multiple levels. The platform is multilingual and currently available in English and Portuguese, using speech synthesis when available. Can be used by patients in clinical or home environments, in a supervised or autonomous way, providing tools for enabling the setup and integration of smart environments.

The user profile and game model are central parts of the framework model. Adaptation is a concept that must be available for better respond to users' needs. Data acquisition and analysis is vital for building a knowledge base allowing learning and adaptation. The platform knows patients by their profile. Therapists can manage and monitor patients and patient exercise schedules and consult and update the patients' profiles. Patient-specific SG can be designed, based on the patient profiles, allowing the personalization of exercises, with data collection of exercise results and sensor samples.

The platform provides a data collection repository and tools for data analytics. Data collected allows the use of ML techniques for retrieving relevant information. The concept includes the possibility of extending the platform by integrating with external applications and their data collection implementations. Data analysis provides information about exercise performance and patient progression. By providing a web services API, the platform is open to the possibility of expansion, integrating with applications and devices that consume it. Actuation devices expand the applications environment promoting more immersive experiences and should be low-cost IoT devices to be affordable both by clinics and domestic users.

4.1. System Architecture

Cloud-based server with 3 main roles: assuring the backend functionalities, a distinct frontend for each platform actor and providing a set of public web services. Client applications can be web browsers, third-party applications, or IoT devices. Users access the platform through a web browser or a web application. Third-party applications integrate with the platform by consuming the provided API.

4.2. Knowing the patient

The patient profile needs to be able to model therapeutic needs of the patients. It is the data structure gathering information about skills and needs. Maintains the base information allowing the system a first iteration at personalization. Each patient has a current profile (Fig. 2). Profile changes are registered and timestamped. The personal information refers to relevant patient identification data including name, birth date and gender. Biometric data record relevant patient data such as arm length or affected side. Patients can require interventions in one or multiple therapy categories. Four categories are available: Physical, Speech, Music, and Cognitive. Therapists can manage the current

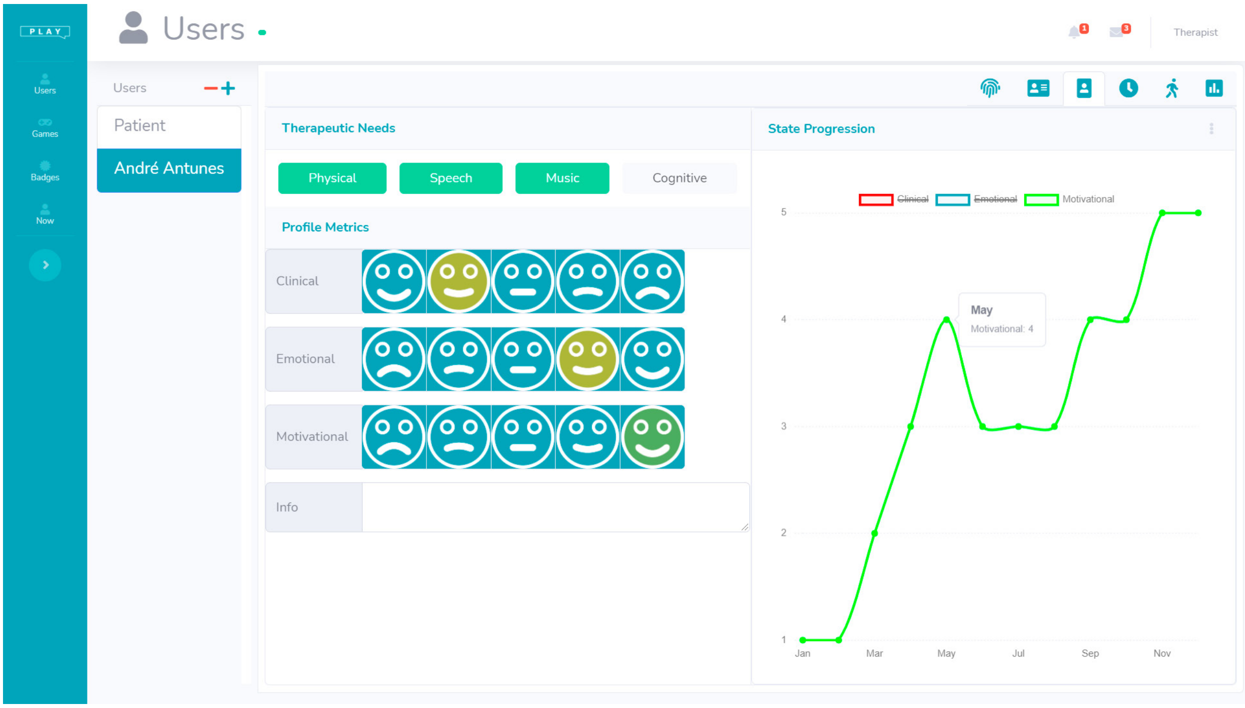

Fig. 2. User profile

therapy categories needed by the patient. These settings are used by a recommendation system for suggesting adequate games and actions for specific patients.

Platform usage history provides valuable information for the patient profile. Game results and sensor samples also provide data for assessment of user progression and profile updates. A pseudo-Likert scale with 5 stages is used for assessing and keep track of 3 distinct metrics. The profile allows tracking and update of the current state of therapeutic severity. This value is managed by the therapist as a personal perception evaluation. The current emotional and motivational states are also available, also using a 5-stage scale. State changes are registered, and states progression can be assessed. The user profile can provide information for external applications, allowing the ones that support it, an extra level of adaptation and personalization of the application's contents and flow, for the current user state and therapeutic needs of that user.

4.3. Modelling exercises

Games must take in consideration the SN of patients. To model the therapeutic exercises, the framework proposes a game model based on actions and parameters, for added flexibility. Each action can have a set of configurable parameters. These parameters define the configurable parts of the action when defining a game structure. The game model consists of game structure and configuration. The game structure is based in actions, that can be organized in sequences. Sequences of actions can be grouped as levels. The game action model tries to provide a way to contextualize and frame actions to be modeled in the platform. Distinct actions are modeled for specific therapeutic interventions. Every game in the platform must follow the game model.

This platform provides the tools for designing SG (Fig. 3), with games becoming available in the patient frontend (Fig. 4a). Therapists can also design game structures for third-party games. As example, an external game (Astro) consumes the PLAY API, retrieving game structure and configuration, instantiating the game model, and sending results and samples to the server (Fig. 4b).

A configurable reward system allows acknowledging users achievements using the platform for promoting motivation. The reward system allows the creation of rewards to be provided to patients based on a previously setup criteria. Criteria used for reward setup include, currently, game usage, and time and score of game actions performance. A

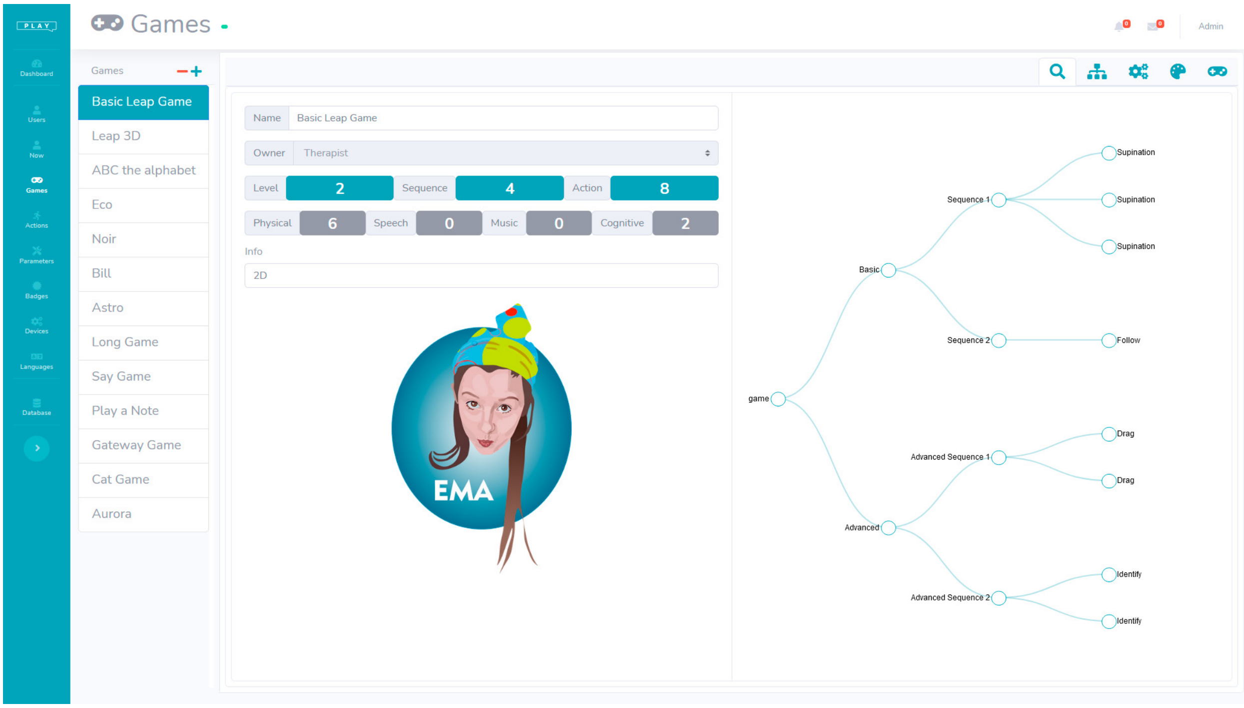

Fig. 3. Game design

set of comparison operators together with a reference value allow to define the conditions for attribution of a specific reward.

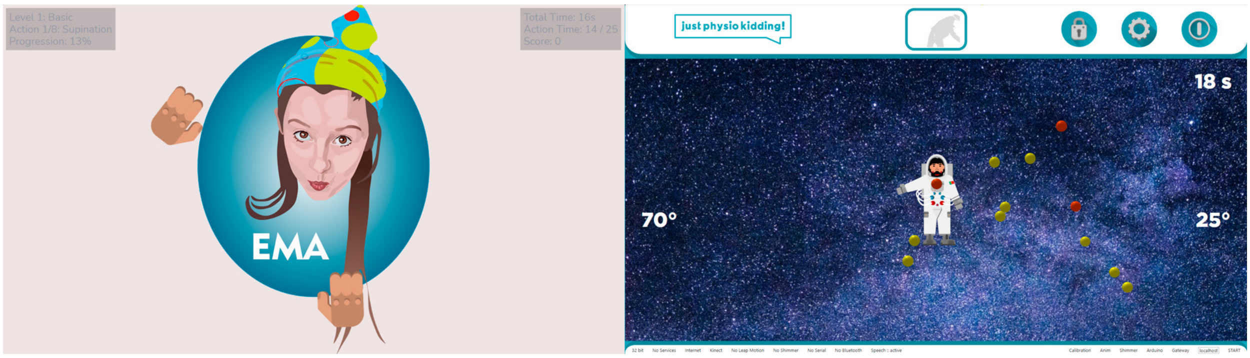

Fig. 4. (a) Platform game and (b) External game

4.4. Integrating with the platform

An API is provided as a web service and is the platform access point to data management, provided functionality and interface for external applications. Using JSON as data format and following a RESTful approach, the API provides registration and authentication services for the applications and users. Game services are provided for exchanging game information as structure and actions, results, and samples. Device services allow actuation devices registration and authentication. Interaction services provide device management and control.

The API provides authentication services for external applications. Before the patient starts playing, the game structure and configuration parameters are requested from the server. Applications implement the necessary game logic for game execution. During the playing of the game, game flow variables, such as time and score, are sent to the server for real time monitoring. Games can be monitored, by the therapist, in the platform frontend. Any game parameter updates, or user notifications can be sent to the game in real time. Any game action that has not been played yet can have its parameters updated with a real time update of the game action in the patient frontend. This feature allows therapists to correct and adjust game parameters if they detect that need during the game. Sometimes increasing the remaining time for completing a required action is enough to prevent patient frustration. Game results and samples are sent to the server after game completion. The API process flow is summarized in Fig. 5.

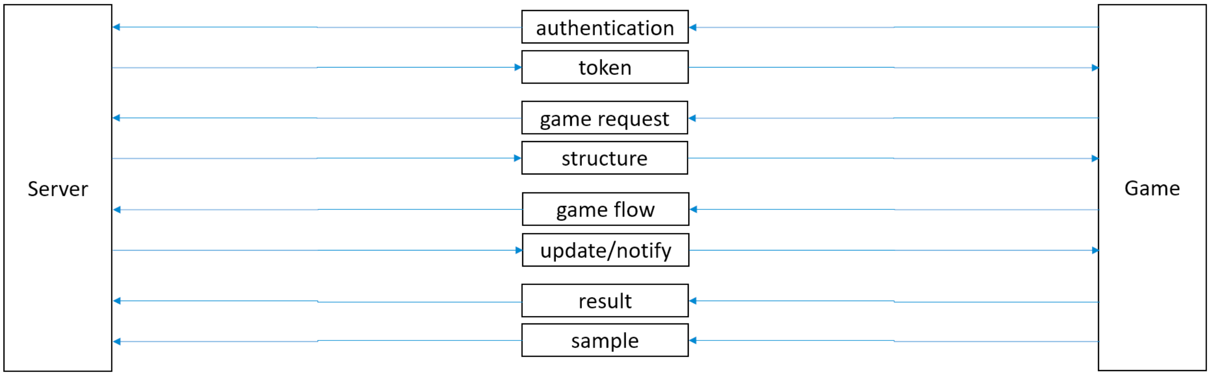

Fig. 5. API process flow

4.5. Data Collection

Therapists need to evaluate the patient performance when executing the game. Every executed game produces game results, based on time and score, that can be compared and evaluated. To be able to compare results, a standard system should be used. Depending on the specific game and sensors used, the game can capture samples of the patient skeleton joints for posterior analysis. This data sampling allows movement reconstruction providing a tool for performance analysis. A patient profile report provides the current state of the patient.

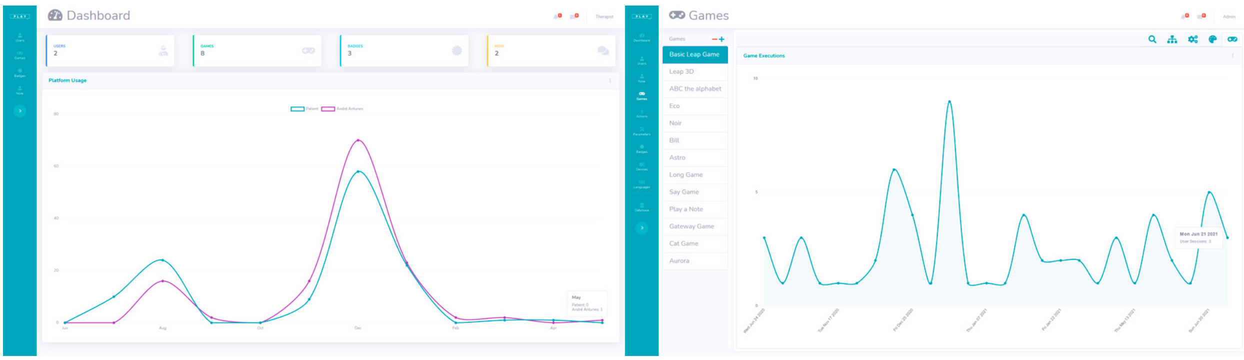

Fig. 6. (a) Therapist dashboard displaying user usage data and (b) Game usage data

5. Conclusions and Future Work

This research provides a model for the design of SG focusing on children with SN. A platform for clinics, therapists and patients was implemented and deployed. The platform allows therapists to design personalized SG addressing specific patients needs. The game model provides a flexible tool for game design, allowing the creation of new games focusing distinct therapies, for a more inclusive therapeutic response.

The framework and platform are stable as starting point for continuous improvement. New therapeutic actions can be modelled and integrated allowing a wider range of possible interventions. Increasing the hardware support for new sensors and actuation devices will provide extended possibilities of interaction during games and exercises. Extending the data analytics tools in the platform for better analysis capabilities, and research and implementation of machine learning algorithms for further optimization of adaptation and personalization, are possible interventions.

External applications can integrate with the platform using the provided API. The API is a valuable tool for integration with other applications, platforms, and devices, and could be further explored and expanded.

A study with therapists will assess model validity and platform usability.

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