On supporting Parkinson's Disease patients: The i-PROGNOSIS Personalized Game Suite design approach

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***Abstract*—The use of serious games in health care interventions sector has grown rapidly in the last years, however, there is still a gap in the understanding on how these types of interventions are used for the management of the Parkinson Disease (PD), in particular. Targeting intelligent early detection and intervention in PD area, the Personalized Game Suite (PGS) design process approach is presented as part of the H2020 i-PROGNOSIS project that introduces the integration of different serious games in a unified platform (i.e., ExerGames, DietaryGames, EmoGames, and Handwriting/Voice Games). From the methodological point of view, to facilitate the visualization of 14 game-scenarios, the system interface and the PD contexts, the storyboarding technique was adopted here. Overall, the realization of the PGS sets the basis for establishing a holistic framework that could aim at improving motor and non-motor symptoms, in order to inform health care providers and policy makers for its inclusion in routine management for PD.**

Keywords—Personalized Game Suite; Storyboards; Parkinson's Disease; i-PROGNOSIS

I. Introduction

The i-PROGNOSIS project is an EU HORIZON 2020 project (www.i-prognosis.eu) that aims to create an intelligent ICT-based approach for early Parkinson's Disease (PD) symptoms detection and early intervention in older adult's everyday life, promoting Active Healthy Ageing, introducing new ways of health self-managing tools. Apart from the early PD risk detection, the i-PROGNOSIS project proposes appropriate ICT-based interventions, tackling the risks that are related with the effect of PD on the health condition of the older adults that exhibit PD symptoms, namely: frailty (due to reduced physical condition/skills), falls (due to decreased flexibility, balance/gait stability) and depression (due to chemical changes in the brain and frontal lobe under-activation). The proposed interventions are realised via the i-PROGNOSIS platform, consisting of a game-based suite Personalised Game Suite (PGS) [1], holistically supporting in a personalised way: muscle tension reinforcement, walking pattern/posture reestablishment and gait rhythm guidance, dietary habits adaptation for reduction of constipation/depression, expressive face encouragement, natural blinking reestablishment, depression/ anxiety treatment, handwriting pattern correction/reestablishment, dysathro- and hypo-phonia reduction, improved pattern of relaxation and sleep quality, facilitating communication with others and socialisation. In i-PROGNOSIS intervention Platform, integrated technology modules will be developed to monitor and support older adult's physical and emotional status enhancement, towards the decrease of the PD-related risks and increase of their quality-adjusted life-years (QALYs).

Recent serious games-based approaches related to PGS PD areas were taken into account, namely: a) for the ExerGames: gait mechanics [2-4], presence of tremor [5], [6], bradykinesia and limited range of motion [7], [8], balance and coordination issues [9], [10], abnormal posture and physical status [11]; b) for the DietaryGames: meal mechanics [12], [13], daily meal distribution [14], preferred food characteristics [15], dietary quality [16]; c) for the EmoGames: non-motor symptoms, psychological issues, depression [17], and hypomimia [18]; and d) for the Handwriting-Voice (H/V) Games: handwriting [19] and voice [20], [21] mechanics.

II. Proposed Personalized Game Suite (PGS)

A. Main Characteristics

The PGS aims to integrate different serious games in a unified platform, taking into account the early stage PD patients' needs and the identified user requirements [22]. As a first step, the i-PROGNOSIS PGS concept was defined, reflecting a common framework to be followed for each game design. In general, Fig. 1 illustrates the dynamic and interdependences of the different serious games adopted in the PGS (i.e., ExerGames, DietaryGames, EmoGames, Handwriting/Voice (H/V) Games), based on five key transversal aspects that are considered to all games, namely:

- *Data types and acquisition devices.* The PGS platform will support certain acquisition devices/controllers. Microsoft Kinect will be the main device for the ExerGames, while touch screens and cameras (tablets' built-in) devices will be utilized by the PGS in a common and transparent way. The output of these devices will follow a standard data format.

- *Data exchange, storing and analysis*. The PGS data storage will be common for all the games. It will be provided through a database and a common API exposing all the data exchange functionality storying and analysis. As for the analysis, general functions will analyse in-game metrics in a common way (average value, deviation, how many times a game was played, values forecasting, etc.) while more complex analysis will take place for each game separately and when this is needed.
- *Safety and feasibility issues*. The PGS will constantly provide instructions and hints to the patient on how the game should be played. When deviation from the proper game play is detected, the game will inform the user in order to avoid injuries or other issues.
- *Personalization and Socialization issues*. Regarding Personalization issues, the games will make the patients reaching their goals progressively in order to keep them in the flow zone which represents the feeling of being complete and energized focus in an activity with a high level of enjoyment and fulfilment towards increased adherence. The games will track the patients' performance (e.g., maximum angle) and will set an intermediate goal just above the patients' average performance. For instance, the physiotherapist had configured the exergaming session to make the patient reach a certain level of leg stretching (i.e., 40 degrees); however, acknowledging the patient's limitations (i.e., history in game measurements show a limit of 25 degrees) the game encourages the patient to reach the pre-set level, progressively. In other words, the game sets the goal of 30 degrees and when this is well accomplished, it further increases the target to 35 degrees until it reaches the physiotherapists configuration.

  Moreover, socialization aspects will be incorporated in the PGS in a way that will make the games more appealing for the patients, in order to increase the levels of engagement. Friendship, participating in groups with others (sharing a common gaming goal) and leader boards will be used as tools for promoting either collaboration or competition among the patients.
- *Reward system and output parameters*. The PGS rewarding systems will run throughout all the games and activities of the platform. The patients will be rewarded ranging from a patient's personal achievement to team achievements. As above, the rewarding system will be applied to increase the adherence levels.

B. PGS Design

The main aim here is the establishment of the design of the different Games (i.e., ExerGames, DietaryGames, H/V Games and EmoGames) based on the early stage PD patients' needs and the identified user requirements [22].

For this purpose, in particular, the storyboardthat tool (http://www.storyboardthat.com/) was adopted, in order to better visualize and illustrate in a sequence of images the main structural elements of the game-scenarios.

In fact, seen as hierarchically structured graphs sequences, the Storyboarding technique has been revealed as common technique in Human Computer and Interaction field and design for facilitating the demonstration of system interfaces and contexts of use [23].

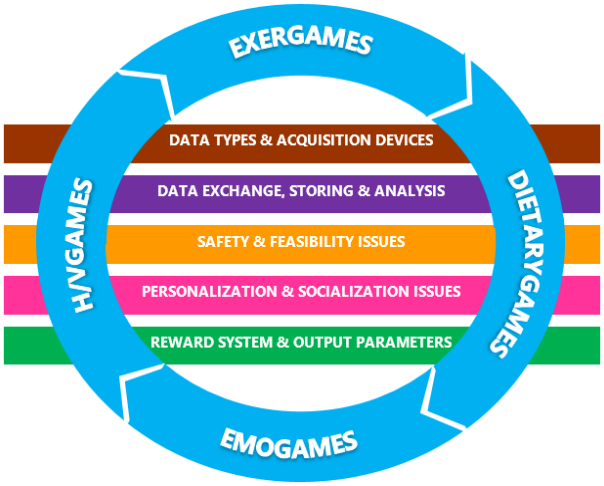

Figure 1. The i-PROGNOSIS Personalized Game Suite (PGS) approach.

III. PGS Structural Outcome

Considering both the principles behind the framework presented in Fig. 1 and the evidence-based in serious games evidence from the relevant literature review, 14 different Storyboards were designed (see Fig. 2). Moreover, the description of each game-scenario/storyboard, along with the game-levels and game-objectives are presented in Table I.

TABLE I. Structural Characteristics of the PGS Games

EXERGAMES	
Game Scenario 1	
Title	**Picking Citrus Fruit**
Task	To march on a pleasure-environment. During the walking, the users are asked to pick Citrus Fruit (lemons and oranges) from different trees.
Description	Users move to the right to pick lemons (using the upper limb) and to the left to pick oranges (using upper/lower limb) from the trees for the corresponding baskets, following the screen instructions. To simulate the climbing (on the left) users should march and pick the oranges simultaneously. At the end of the game, the motivational message will change according to the total score reached (e.g., "Congrats, you finalized the game! Total Score: 30/70. Actually, with more 20 fruits picked you could reach the next level! Try harder next time!").
Game-levels	Users should follow the doctors' recommendations, when pick the highlighted fruits (since the fruits will appear in low, medium or high positions). The time-duration of the highlighted fruits will change according to the level of difficulty.
Game-objectives	Practicing the walk movement; Improving gait mechanisms; Improving balance and coordination aspects.
Game Scenario 2	
Title	**Fishing**

Task	To move the body (front and back), to control the boat's position and to collect as many fishes as possible.
Description	The users control the position of a boat in order to fishing the moving fishes, adjusting their center of mass. The user's posture is monitored by the Kinect and controls the boat's position on the horizontal axis. The fishes come from the left side and move towards the right side (horizontal axis). At the end of the game some motivational messages appear (e.g., "You collected 20 fishes and one shark hit your boat. Very good. Let's fish again!!)
Game-levels	Once the boat collides with a fish, the fish is collected and the score increases. The shark will appear more frequent. The speed of the fishes will increase.
Game-objectives	Improving balance; Improving upper and lower limb strength.
Game Scenario 3	
Title	**Kinematic Orchestra**
Task	To pick figures that appear randomly on the screen, by using up/down right/left and/or circular hand movements.
Description	Several figures that take part in a conventional music score appear in the screen in a dynamic way, one by one, during ~2 minutes. Different instructions appear in the screen (e.g., eights/quarter/half/whole notes correspond to 1 point; quarter/half rest correspond to two points). At the end of the game some motivational messages appear (e.g., "Congrats! Since you reach the maximum score you can listening your composition!").
Game-levels	According to the doctor's recommendations, focus will be given to particular movements (e.g., the figures will appear in low, medium or high positions on the screen).
Game-objectives	To reduce the presence of tremor; To reduce symptoms related with bradykinesia.
DIETARYGAMES	
Game Scenario 1	
Title	**The Eatwell Plate**
Task	To re-educate and inform users about the foods that make a balanced and healthy diet, based on the Eatwell Plate recommendations that divides the foods and drinks into five main groups. The users should match each food in the corresponding food group division by using the left/right hand for the foods that are presented in the left/right side of the screen.
Description	The users just have to move the hand over the different parts of the food groups shown on the plate to hear what the Chef i-PROGNOSIS has to say. They can also read the information at the bottom of the plate (e.g., "Water is a healthy and cheap choice for quenching your thirst at any time. To avoid constipation issues drink at least 6-8 glasses of fluid a day!"). At the end of the game some motivational messages will appear (e.g., "Congrats! Four different food groups were matched correctly! Take a break and drink a glass of water, you deserve it!").
Game-levels	If both hands are used simultaneously, extra points are given. The level of difficulty depends on of the amount of time spent to finalize the task. If the users complete the previous task successfully they can start the Sudoku Game for each food group (e.g., for the Fruits and Vegetables Sudoku game each horizontal row, vertical column and 3x3 box must contain all nine foods related with F&V food group. Three different levels of difficulty (i.e., Easy, Medium, Hard) will be considered.
Game-objectives	Encouraging/Re-educating users to adopt a healthy and balanced-diet approach, based on the Eatwell Plate recommendations.
Game Scenario 2	
Title	**Retraining of Eating Behaviour**
Task	To re-train deviations from "normal eating behaviour" (i.e., eating rate, bite and chewing frequency). Each user is trained by a short virtual, with meal-like exercises, sitting in front of the TV using Kinect technology.
Description	The motoric exercise will focus on training bite/spoonful frequency. Ideally, this exercise is executed around regular meal times in the day. The gaming screen (TV) is split in two parts, namely: 1) the users own avatar, and 2) the "ideal eating" avatar. When the user starts to eat, the goal is to mimic the ideal eating style displayed by the avatar. At the end of the game some motivational messages appear (e.g., "Great job! You scored 70 out of 100!!!).
Game-levels	Perfect compliance with the ideal eating style avatar gives a perfect score (100 out of 100), while complete lack of movement gives a zero score. The purpose of the game is to progressively train the user towards a perfect score, with a more compliant eating behaviour being rewarded with higher scores in a "dose response" manner, until the user reaches 100 out of 100.
Game-objectives	Primarily, this game will focus on training the user towards a pre-set (and optimally, personalized) bite/meal number. Through this, the user will re-train their innate bite frequency, directly affecting the users eating rate through modifying the overall meal duration. Secondarily, this game might affect the chewing rate/amount of chewing per bite for each bite. The progress in the real behaviour is quantified through the meals taken on Mandometer, by comparing the relevant extracted indicators at the before/after points.
Game Scenario 3	
Title	**Photo Diary**
Task	Users should upload real photos related with a full day of meals (i.e., breakfast, lunch, and dinner) and snacks.
Description	The Photo Diary game starts after the user uploading different photos related with meals and snacks. Each horizontal row, vertical column and 2x2 box must contain all upload photos related with the Breakfast/Lunch/Dinner meals and Snacks. At the end of the game, motivational messages appear (e.g., "Congrats! Go to the next level!").
Game-levels	Based on Sudoku game logic, three different levels of difficulty (Beginner, Hard, and Expert) are considered. To start the next level each player has to upload 9 photos, meaning that each horizontal row, vertical column and 3x3 box must contain all upload photos related with each meal and snacks. For instance, in the Expert level, the users must categorize the photos that they uploaded in the system as healthy or unhealthy meal/snacks. Then, to complete the task successfully, each horizontal row, vertical column and box must contain one full day of Heathy or Unhealthy meals (breakfast, lunch, dinner) and 1 snack.
Game-objectives	Improving the categorization of the food groups and awareness of a balanced combination of (un)healthy meals/snacks in a full day.

EMOGAMES	
Game Scenario 1	
Title	**Rhapsody of Faces**
Task	To identify the happy and positive faces.
Description	The user has to identify the happy and positive faces. For every correct selection, more time to continue is given to the user. In case of a wrong selection, the countdown watch will run faster. A wrong choice is when the user selects the wrong one or misses to select a correct one. After selecting the correct photos, a new frame with 4-8 photos is brought up. The final stage presents the correctly identified faces as well as the last wrong one. At the end, motivational messages appear (e.g., "Congratulations! You found 2 happy faces in less than 1 minute. Great work. Try reaching higher level next time!!").
Game-levels	As long as the users progress, the happy faces will not be so expressive which will make more difficult to identify them.
Game-objectives	Motivating (positive) facial expressions; Encouraging facial expressions.
Game Scenario 2	
Title	**Imitation Game**
Task	To imitate faces.
Description	A score of the similarity is presented on the right side. The highest score is recorded. The users must blink the eyes rapidly for a couple of times when finish. Apart from counting this as one succeed level, the similarity level is also counted and contributes to the final overall similarity level. When highest level is reached, the user is presented on the right corner with her/his photo. When the user does not pass the threshold, the game ends. At the end of the game, some motivational messages appear (e.g., "Congrats! You reached the 2nd level and you score 8.7 similarity points.").
Game-levels	As the game evolves, the faces that show up and need to be imitated by the user will be more difficult requiring the user to be more expressive.
Game-objectives	To improve facial expressiveness.
HANDWRITING/VOICE (H/V) GAMES	
Game Scenario 1	
Title	**Pop the Balloons**
Task	To pop the appearing balloons on the screen.
Description	Once the user starts the game, the timer will count down from ~120 seconds. The user will see different colored balloons appearing on the screen, labelled with different numbers or markers, covering the dynamic range (from *pianissimo* to *fortissimo*). For instance, in order to pop a red balloon, the user needs to pronounce an "a" at the right volume for two seconds. On the other hand, to pop a green balloon, the user needs to pronounce a "u" at the right volume for two seconds. At the end, the final score appears in the screen.
Game-levels	When finishing a level successfully, the difficulty increases in the next level. In the first level, only two different kinds of balloons will appear. The user has to pronounce a fixed vowel with either soft voice (piano) or with loud voice (forte) to "pop" the specific balloon. In higher difficulty settings the user has to pronounce these vowels on a finer dynamical range (e.g., *piano – mezzo piano – mezzo forte – forte*) to pop the correct balloons. Also, the user is asked to pronounce different vowels on higher difficulty levels, however the focus is on practicing voice dynamics.
Game-objectives	Practicing voice dynamics.
Game Scenario 2	
Title	**Catching Voicimons**
Task	How many Voicimons can you catch within 2 minutes?
Description	Voicimons (mash-up of "Voice" and "Pokémon", i.e., cute little pets with visible vowel letter) appear randomly on the screen (one or a few at a time). By uttering the right vowel for 2 seconds the Voicimon gets caught. If the user's utterance is shorter than two seconds or the wrong vowel is uttered, the Voicimon escapes. The Voicimon also disappears after some time. Some bad Voicimons sometimes appear on higher difficulties, where the user is asked not to catch it. If the user catches a bad Voicimon, some points are subtracted. The score is displayed after the two minutes elapsed, taking into account the vowels caught.
Game-levels	In the easy levels, only three different vowels will appear and only one at a time. Also, the time the Voicimon stays will be generous. After finishing a level successfully, a new harder level is unlocked. In higher levels, new vowels will be introduced and more Voicimons will appear, but they also will disappear faster.
Game-objectives	Practicing different vowels.
Game Scenario 3	
Title	**Good Night Story**
Task	The user has to read a Good Night Story for the little virtual kids that cannot sleep, for instance: "*Once upon a time, there was a prince and a princess, who live in a big castle*."
Description	One sentence at a time is displayed on the screen as well as a "slumber-o-meter" (that serves to measure the sleepiness of the kids). By reading the sentence in a clear and accurate manner, the kids get sleepier. Depending on the user's performance the kids fall asleep (or not). In each level, a few sentences have to be read, one sentence at a time. Furthermore, a "slumber-o-meter" is displayed on the screen, which measures the sleepiness of the little kids. If the user speaks to quiet or not clear enough the slumber-o-meter reaches low and the user loses the game if the kids do not fall asleep. If the kids fall asleep, a new harder level is unlocked.
Game-levels	In harder levels, the amount of text to read will get larger and the text must be read more clearly and accurately to win the level.
Game-objectives	Practicing narration and natural speech.
Game Scenario 4	
Title	**Car Race**
Task	The user participates on a virtual car race.
Description	First the user gets a car to participate on a car race. Using the fingertip/stylus, the car can be steered. By

	time, the car gets faster and faster (e.g., from 40 to 50Km/h), and the streets get more and more difficult. The longer the user proceeds, the more points the user gets. When the user hits something, or drives outside the roads, points are subtracted. After the course is finished, the level is finished and a score is displayed. By achieving a specific number of points higher levels are unlocked.
Game-levels	In higher levels the course gets more difficult by increasing the speed, by increasing the number/types of obstacles and by increasing the course length.
Game-objectives	Maintaining writing skills; Improving finger/stylus movement.
Game Scenario 5	
Title	**Find me**
Task	To find the missing letters.
Description	The user has to enter one letter a time to guess a word. To write a letter, the user has to select a letter first. To write a letter, the user must slide the blue point over the whole segment. After sliding several segments a whole letter is entered. In order to see if the letter is correct, the user must push the confirm button. If the answer is incorrect, the letter is deleted and the user will get a penalty point. If the answer is correct, the letter is saved. The level is completed if the user finds the correct word. However, if the user collects the maximum number of penalty points, the game is over.
Game-levels	In higher levels the user is asked to guess more difficult words with a larger number of letters.
Game-objectives	Maintaining writing skills; Improving the stylus movement.
Game Scenario 6	
Title	**Writing letters**
Task	The user has to trace the letter using a stylus on the screen.
Description	Simple letters are displayed on the screen. The user has to redraw the letters using a stylus. Depending on the level, cues like horizontal or grid lines are displayed. The user must connect the dots with a line. Each dot that the user reaches, one point is given. Some motivational messages appear on the screen (e.g., "Try to stay inside the grey space."). If the user leaves the grey space he/she will lose a point. The level is completed just if the user reaches the last dot.
Game-levels	Higher levels will be unlocked if the user gets a good score in the previous level. In higher levels the grey space gets narrower and the user is asked to draw whole words.
Game-objectives	Improving/Maintaining Writing skills.

From the structural characteristics of the tabulated game scenarios of the PGS it is evident that almost all the fundamental PD-related issues are addressed in a gamified way. Moreover, the storyboards of Fig. 2 visualize the basic phases of the proposed game scenarios, providing the bed-set for their further development in the PGS platform. Seen as a first step of the process of the games design, the use of the Storyboard technique revealed to be a useful tool to clearly define the flow of each PD game-scenario, interactions, technical and graphic details, in a single, flexible and collaborative environment.

IV. CONCLUSIONS

The PGS tackles the PD symptoms as it incorporates the practicing of walk movement, improvement of gait mechanisms, balance and coordination aspects, encouragement and/or re-education of healthy and balanced diet, retraining of eating behaviour, improvement of facial expressiveness, improvement/maintaining of writing skills, practicing of narration/vowels/letters and speech dynamics. Via the PGS, the management of the PD patient's condition is placed within a serious games context, in order to improve, sustain or slowing down its progressive deterioration, taking into account safety, feasibility, personalization, socialization, and behavioural change aspects.

As a future work, we intend to collect feedback/suggestions from the PD patients' and medical experts related with the storyboards, in order to involve them as co-creators of the game-design. In addition, it is our intention to smoothly integrate the artificial intelligence concept into the games, including the adaptation algorithm that has the capability to change/readapt the games and the different levels of difficulty, according to the PD needs and performance/social engagement of each user.

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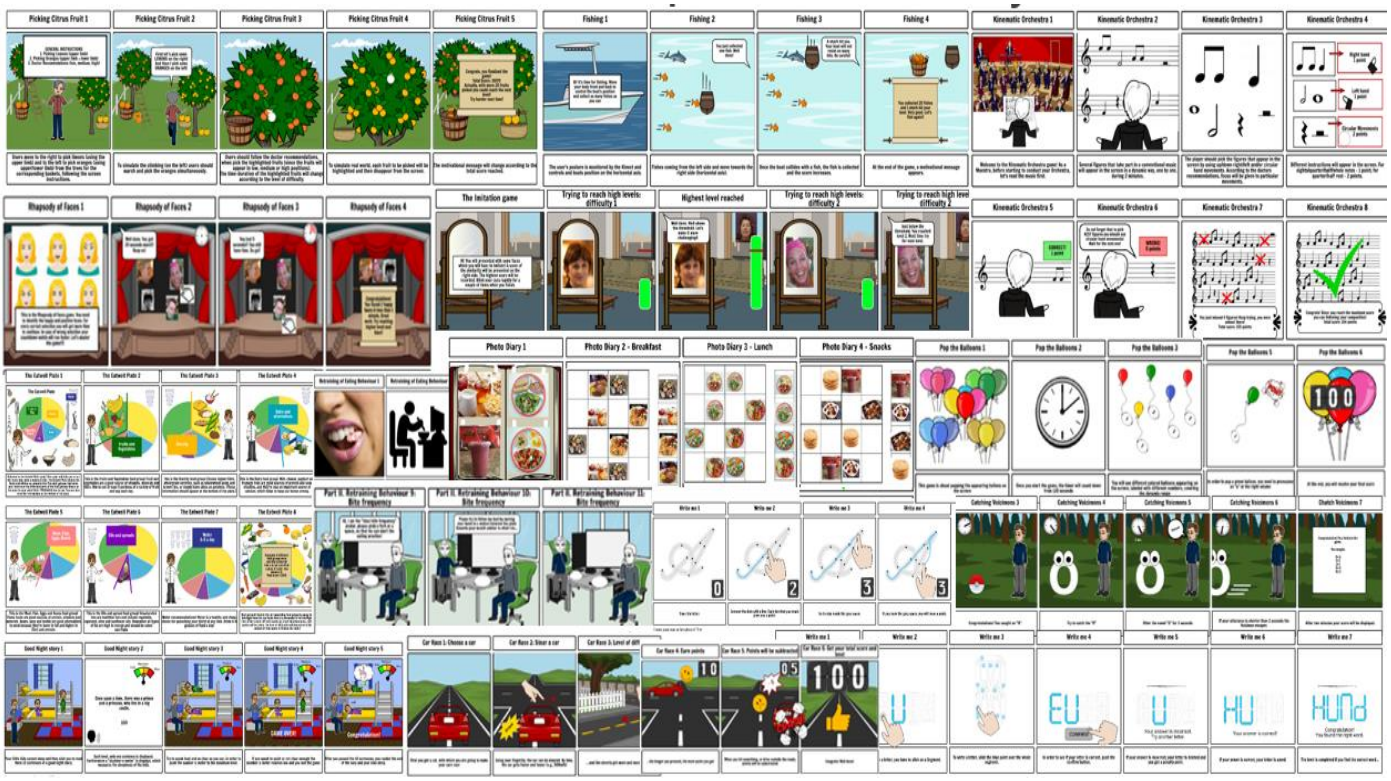

Figure 2. General visualization of the 14 Storyboards integrated in the PGS including the ExerGames, DietaryGames, EmoGames, and H/W Games, using the storyboardthat environment.

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