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Pathway+ Mobile Pedagogical Assistant to develop meaningful pathways to personalised learning

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Intellectual Output 3: Mobile pedagogical attention/engagement measurement App Technical Design

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1. Introduction

The main goal of Intellectual Outputs IO2 (Games) and IO3 (Attention/Engagement Measurement App) is to develop an integrated mobile pedagogical attention/engagement measurement application. The games described in IO2 act as 'Continuous Performance Tests'. Students with mild and moderate learning disabilities play them and the outputs of the games (such as errors and reaction times) help us to understand the patterns in the sensor data which are collected whilst playing these games. Hence the games developed in IO2 must have built-in measurement methods that make it possible to record for following activities:

- Eye gaze
- Body pose
- Head position
- Facial expressions
- Interaction tracking

Once our algorithms have been trained using the output of the games, the App can then be used in inclusive and mainstream classrooms, and use non-labelled sensor data and be able to predict the engagement and attention of students with mild and moderate learning disabilities. Teachers can then use this attention/engagement prediction and use the practical advice offered in IO4 (Teachers' Handbook) concerning suggested teaching approaches and methods to best include each student, and help them reach their full potential.

2. Application design & considerations

This report covers the technical design of the Attention/Engagement Measurement App derived from the requirements established in the early stages of the Pathway+ project – namely IO1 - Descriptive map of effective pedagogical approaches; and IO2 – The Games. The App uses the output of the Games (IO2) to label sensor data collected whilst students with mild and moderate learning disabilities are running the app. This lets us to train our algorithms to allow accurate prediction of attention and engagement in these students.

Teachers can then use this prediction to understand which approaches and teaching methods will best promote their inclusion in classrooms. The 'What's Next' section in the Teachers' Handbook (IO4) gives practical guidance and how to map this prediction to a suitable range of pedagogical approaches and interventions established in our research phase (IO1).

2.1 Design decisions

Along with the overall measurement requirements specified above, partners identified non-functional requirements regarding platform portability. Therefore, for the cross-platform development platform Xamarin has been selected. Cross-platform distribution has been identified as a very important requirement, since it will ensure future code reuse and easy platform portability on the most commonly used mobile platforms, including both Android and iOS.

Using Xamarin for the mobile application development will ensure cost-efficiency and a reusable code base, without losing native application experience and performance.

The Xamarin platform allows full hardware support, which is very important considering the diversity of sensors required to support necessary measurements.

The iPhone X currently tracks eye gaze direction using a built-in facial scanning unit which can be accessed with the ARKit SDK [1]. As Apple released ARKit 2.0 with many brand new APIs and features for Augmented Reality Development, and supported by the Xamarin platform, the application will be built for iOS operating system initially. In the future, it is expected that the sensors will be adopted in high end Android devices, and using Xamarin will allow for easy transferability to the Android operating system.

The use of EEG (via the muse) and electrical muscle activity (Myo band) were considered in the project plan and initial design, however testing of devices in the initial phase of the project revealed them to be of limited use, and potentially distracting to children with mild and moderate learning difficulties. It was also considered architecturally and physically advantageous to have all the sensors contained within a single device.

2.2 Sensor data

The main outcomes from the continuous performance test are:

- Learner response time (measured from the time a slide is shown to when the learner reacts)
- Learner response outcome (True Positive, True Negative, False Positive and False Negative).
- Difficulty / Signal Strength (how many simultaneous images were on the screen, how many total different images in the image? What was the maximum response time allowed?)

The application collects the sensor data. Using ARKit 2.0 the application will be able to record 10 sensor readings per second.

- CPT slides are represented with squares.
- Each slide is spaced apart because there is a pause (inter-stimulus time) from one slide to the next.
- Sensor data is lined up using a unified timeline against the CPT slides.
- The CPT provides us with reaction time and errors which are then also used to label the sensor data, train our algorithms, and hence allow us to predict and infer attention and engagement from unlabelled data in the future.

3. Functional Requirements

A list of functional requirements has been compiled, covering the essential behaviour of the app. These are listed below, grouped under 4 headings: the CPT game, data collection, settings and data review and export.

3.1 Functional requirements for CPT game mode

FR1. Continuous Performance Test game should be a fluid app platform that can deliver the 4 different games, interchangeably – this is the CPT platform.

FR2. The platform will have 4 main views, the CPT game mode (described in detail here), the Live mode, the settings menu and the data review and export view.

FR3. There are 4 different games in the platform. These 4 games are the ones described in detail in the IO2 slides.

FR4. When the CPT game starts the user is presented with the 4 games in picture tiles and must chose a game mode to start the game.

FR5. The CPT platform will allow variable game difficulty experience through a settings menu.

- FR6.** The settings menu will only be accessible with a password.
- FR7.** The settings menu will be in a multi-level expandable list style like the iPhone's settings menu.
- FR8.** The settings menu will allow the administrator to enter a list of predefined users.
- FR9.** The settings menu will allow the changing of total number of slides presented (the default amount should be 48 slides not including blank slides), the slide and blank slide display times, and how many elements display rows and columns grid in the Seek-X, Seek-AX and Seek-AX Quiz games.
- FR10.** The settings menu will also allow the administrator to select or disable any number of sensors. Eye gaze, head pose, gyroscope/accelerometer...
- FR11.** All the above game settings can also be saved and attached to a name from the users' list to be loaded and reused quickly in a future session, the users' default settings can be edited by accessing the settings menu.
- FR12.** The last used game settings are saved and used in a new session.
- FR13.** The CPT platform will always prompt the user to select their name from a drop-down at the beginning of every session from the predefined user's list and then load that user's default settings.
- FR14.** The CPT platform always check to see if the sensors activated in the settings menu are connected, receiving data before allowing a session to start.
- FR15.** The CPT platform shows has a 'sensory debug' mode which can be turned on, in the settings menu that allows the administrator to see the status of external sensor connections, green if they are connected and receiving valid data, yellow if they are just connected and not receiving valid data, and red if they are not connected. This is shown on the top centre of the screen.
- FR16.** A randomized seed is automatically created to generate the randomized slide order.
- FR17.** The CPT platform will create the slide order using the seed at the beginning of the game, using the game specific percentages defined in the IO2 slides.
- FR18.** At the bottom centre of screen during game play, the slide number (not counting the blank slide will be shown out of the total numbers) the student name, time, date and seed string is shown. For example:
Slide 4/48 – Jack – 5:30 – 12/10/18 – HJSND
- FR19.** The platform will show a blank slide between every slide. These blank slides will be shown for 1 or 1.2 seconds, these two values can be changed in the administrator settings menu.
- FR20.** The platform records every button press, press coordinates and time stamp and which number slide it happened on. The platform exports this data in excel format. This is what this data looks like. For the response CC stands for correct commission, WC stands for Wrong Commission, CO stands for Correct Omission, WO stands for Wrong Omission.

Table 1. CPT response table

Slide No.	Slide	Response	Slide displayed	Slide hidden	Press 1 time and coord.	Press 2 time and coord.	Press 3 time and coord.	..	Press N time and coord.
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1	B	WC	5:30:15.5 00	5:30:17. 000	5:30:16.148 – (200,250)				
2	X	WC	5:30:18.0 00	5:30:19. 500	5:30:18.273 – (1005,330)	5:30:18.558 – (500,800)			
3	A	CO	5:30:20.7 00	5:30:22. 200					
4	X	CC	5:30:22.2 00	5:30:23. 700	5:30:22.768 – (760,380)	5:30:23.028 – (350,1000)	5:30:23.208 – (350,560)		

FR21. This data is not stored at the end of the game. The platform will record this data in real time as the game progresses and all data will be available if the game crashes, or if the platform turns off unexpectedly or if the game is exited by the user through the menu.

FR22. Sensory data is collected from the sensors selected in the settings menu and stored in real time as the game progresses. This data will be saved even if the game crashes or terminated or exits. Sensory data is not recorded slower than 1/10 of a second frequency.

FR23. The sensory data will look like the table below:

Table 2. Sensory data table

Slide number	Slide	Date	Time	Eye Gaze	Head pose
1	B	13/10/18	5:30:15.500	(234,987)	(234,987,876)

FR24. When the game finishes or if the game is exited early by the user, the system reports the raw score of the person and their percentage in this way:
percentage: correct-wrong/total-slides * 100

FR25. When the game finishes, the game thanks the user for their time, using a musical sound bite, an animation and the username on the screen.

FR26. When the game finishes, or if the game is exited early by the user, the system reports the raw score of the person and their percentage in this way:
percentage: correct-wrong/total-slides * 100

FR27. At the end of each session, the overall average response time, the average response time of correct responses, the average response time of mistakes is also recorded and is exported at the end of the excel file. Also d' , C and A' and B''_D values from the signal detection theory are calculated. The formulas for those are explained at the end of this document.

FR28. The session data is stored and can always be exported in the future.

3.2 Functional requirements for sensory data collection mode

FR1. The sensory app is the same app as the CPT games app with the CPT games turned off and the machine learning and feedback loops turned on. The administrator can toggle between the two modes in the settings menu.

- FR2.** The sensory app records and collects the same sensory data as the CPT games app.
- FR3.** Just like the CPT games app sensors can be activated or deactivated in the settings menu. Eye gaze, head pose, gyroscope/accelerometer...
- FR4.** Just like the CPT games app the settings can be loaded from one the names in the user list.
- FR5.** Just like the CPT games app the last used settings are loaded for a new session.
- FR6.** Just like the CPT games app the app prompts the user to choose a username from a drop-down menu of all the users from the user list. This populates the settings with that user’s settings.
- FR7.** The app can be run in anonymous mode without choosing a user from the populated user list prompt.
- FR8.** The app gives feedback about the outputs of the machine learning using a traffic light system. The level of engagement is shown in this graded manner.
- FR9.** The app has an ‘affect debug’ mode which shows a scrolling list on the screen of the raw output of the machine learning.
- FR10.** The ‘sensory debug’ mode described in the CPT test game mode can also be turned on in this mode of the app.
- FR11.** The app will always check to see if the sensors are activated in the settings menu are connected, receiving data before allowing a session to start.
- FR12.** Just as in the CPT game mode, sensory data is collected from the sensors selected in the settings menu and stored in real time. This data will be saved even if the app crashes or terminated or exits. Sensory data is recorded at at-least 1/10 of a second frequencies.
- FR13.** The sensory data along with the features from the machine learning process and the machine learning final outputs is stored in real time and can be exported in excel format. This data is stored in real time and is saved even if the app crashes or terminated or exits. The data will look like the table below:

Table 3. Sensory data table for the sensory data collection mode

Date	Time	Eye Gaze	Head pose	Machine learning outcome 1	Machine learning outcome 2
13/10/18	5:30:15.500	(234,987)	(234,987,876)	0.53	0.85

Table columns continued...

...	Feature 1	Feature 2	Feature 3	Feature N			
...	0.38	0.35	0.78	0.62			

- FR14.** The sensory data is stored and can always be exported in the future.

3.3 Settings menu

- FR1.** The settings menu is protected by a password.

FR2. The settings menu has access to the CPT game settings, the active sensor list, and also the pre-defined editable user list.

FR3. New users can be added to the predefined user list and old users can be edited.

FR4. Settings can be changed and attached to existing users from the user list.

FR5. In the CPT game settings, the default game can be chosen, the blank slide durations can be set (there is a minimum of two different durations that a blank slide is shown; they are defaulted to 1 and 1.2 seconds).

FR6. In the CPT game settings, the active sensors are chosen, by default they are all off besides the ones that are built into the device (i.e. in case of the iPhone X the eye gaze, and head tracking and gyroscope/accelerometer).

3.4 Session review and export menu

FR1. The session review is only accessible with the administrator password.

FR2. In the session review view, the administrator can view the CPT signal detection confusion matrix (explained in the Signal detection amendment) and can view the Signal Detection index calculations.

FR3. The administrator can also export in excel format the full data from that session.

FR4. The administrator can filter the sessions by a calendar picker From -> To date selection, participant name

FR5. There is also a select all visible option that can be used to batch export sessions that have been filtered by date or participant names.

FR6. The exported excel file will include 3 sheets, the confusion matrix, the CPT response table and the Sensory data table.

This list of requirements will be prioritised and implemented, with the opportunity to revise and review each requirement within the scope of the project, to assess how critical each one is to the development process.

4. Development Decisions

Not all of the features in the functional requirements have been implemented, and some additional functionality was added. The features not implemented relate to the Muse and Myo band; an assessment of the practicality of implementation, and utility of the data received was made against the much more streamlined use of just the phone sensors, and it was agreed that using the True Depth camera alone would provide sufficient data at this stage of development. Also, the first four games have been developed and piloted, but the fifth game (Seek AX CPT test with quiz) has not been implemented, as a result of the outcomes from early piloting. Our testing groups all have a degree of learning disability, and taking into account the experience in testing the first two games, Type-X and Seek-X in early 2019, it was apparent that the complexity of the Seek-AX with quiz would be well beyond the achievable level of our learners.

Some additional features have been incorporated; additional fields in the settings area of the app allow variation of Number of slides, slide display time, blank slide display time and blank slide variation; an additional matrix size has been created for the SEEK games – there is now the option of

both 4X6 and 3X5. Eye gaze visualization has been modified to be device independent (screen PPI, width and height compensation can be edited to match the device being used); and additionally, modification of the sample window duration (in order to capture engagement, averaged over a period of between 1 and 20 seconds) and tolerance (which affects how readily the indicator will change from red through to green) have been added.

The sensory data collection mode has been relabelled as “Live Mode”. Data captured when in this mode provides on screen indication of the engagement of the student; no data is stored or saved for longer than the sample window duration. This iteration of the app has been developed to show real time engagement to the observer, and the removal of the possibility for storage of this data allows for enhanced privacy.

5. App Screen captures

Below are a selection of screen captures from the app.

5.1 The CPT Game Mode

The app starts up with game selection, the next 3 screens are taken from the Type-X game.

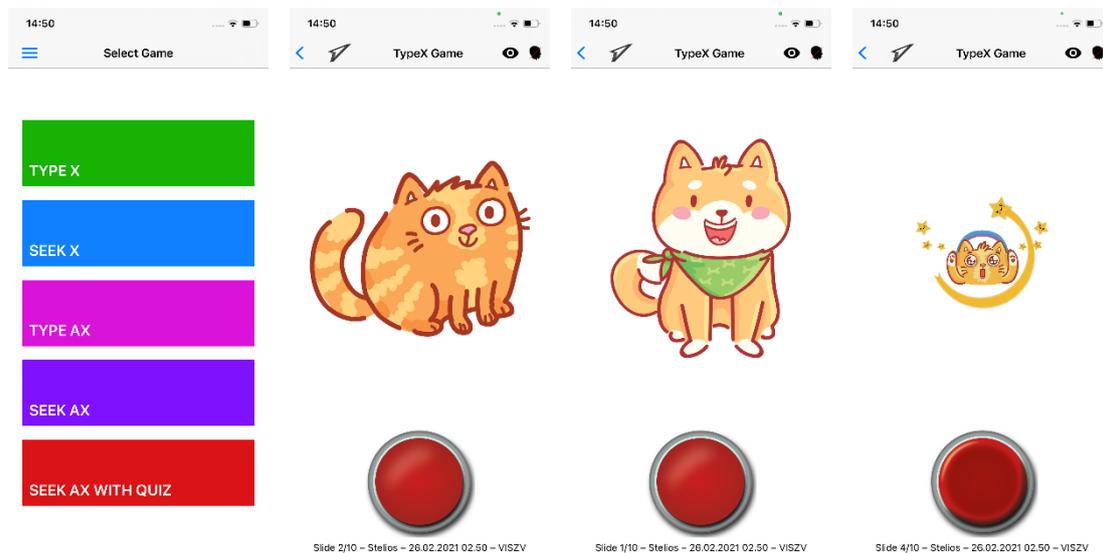


Figure 1 Game selection screen, and 3 screens from the Type-X game (Correct Wrong and Reward screens)

5.2 The Settings and Users

The Settings menu provides access to any game session data for that user, User management, Settings (shown across 2 screens here, access to Live Mode and Language).

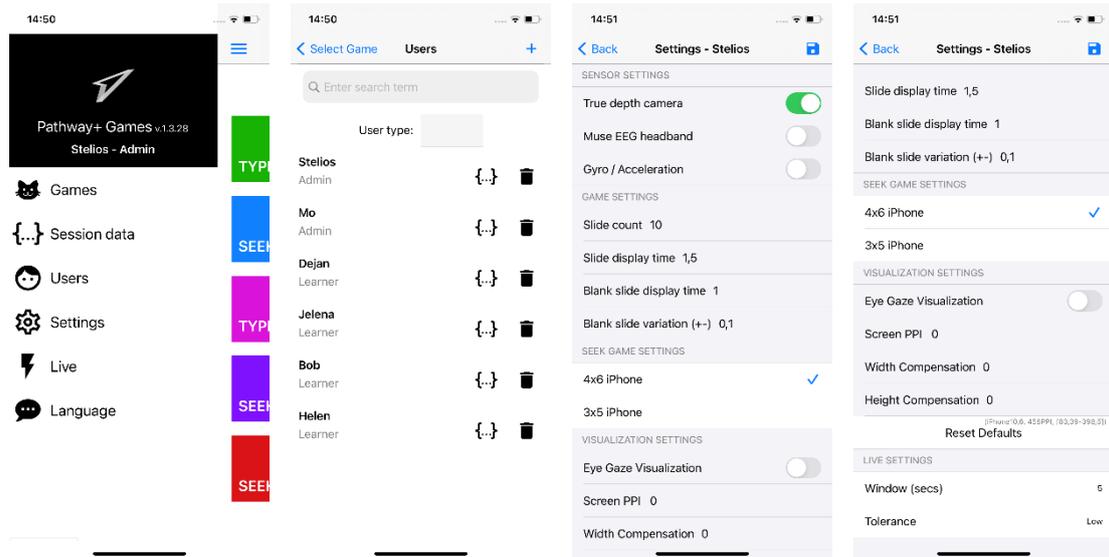


Figure 2 The System menu, Users and Settings (2 screens)

5.3 Live Mode

In Live Mode, the camera tries to track the user's face, and will report red, orange, yellow or green depending on how engaged the user appears to be. It will only report when tracking is active (when the eye at the top of the screen is black).



Figure 3 Live Mode - with varying degrees of engagement

When tracking is not possible, the eye will turn red. (The traffic light indicator will remain the colour it was when the last value was received.)

6. Delivery

The App is hosted on the apple TestFlight Platform. It may be downloaded from the following URL: <https://testflight.apple.com/join/fz2ZeKic>

The app remains in Test Flight at present, and is staged for released to the App Store. Details of the Apps installation and use can be found in "IO5 Manual for Teachers", practical classroom use of the



app is given in “IO4 Handbook for teacher educators”, and we have also produced a practical guide to classroom use of the app in the “What’s Next Handbook”.

7. References

[1] ARKit SDK - <https://developer.apple.com/documentation/arkit> (accessed 26/06/19)