USING CONTEXT WITHIN COMPUTER-AIDED REHABILITATION TO INCREASE MOTIVATION FOR PEOPLE WITH APHASIA

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16/10/2015

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Dms127:3482795

Abstract

Computer-based rehabilitation has been found to be effective for those who suffer from cognitive deficits due to brain injury including people with aphasia (PWA). Most aphasia rehabilitation is repetitive and drill-based, often requiring the patient to practice mentally retrieving words to complete sentences. This can be tiring, frustrating, and sometimes de-motivating for the PWA. Furthermore, there are higher rates of depression in PWA. Depression leads to lowered motivation. The goal of this project is to build an application to aid rehabilitation based on the theories of motivation previously used primarily in education. This project includes phases for understanding current popular rehabilitation methods, evaluating features of current software, requirements gathering, designing. Due to the exploratory nature of the project the lean process was chosen to be used. Three iterations were performed after an initial domain familiarity. The final implementation involved creating two different applications: an online PostgreSQL backed RESTful server with a web based frontend for PWA and the other as a local java swing based question creator tool that allows medical practitioners to create personalised problems.

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1.0 INTRODUCTION

Aphasia affects 16,000 New Zealanders and is more common than Parkinson's disease, cerebral palsy or muscular dystrophy and is commonly caused by either a stroke or traumatic brain injury [1, 2]. Aphasia has a "greater negative impact on a person's quality of life than cancer or Alzheimer's disease" [3]. Rehabilitation for people with aphasia (PWA) is a commonly researched field. Rehabilitation treatment has been shown to create significant improvements in aphasic patients for both long term and short term sufferers where the intensity is at least 2-3 hours a week, clinically alone those hours of rehabilitation are not being met [4]. In an effort to meet the recommended intensity the use of computer aided rehabilitation takes a role as it is both cheaper and more accessible than clinical practices. Computer based rehabilitation methods allow the patient to be "in control of his or her own rehabilitation process, which is an important social model principle and which, no doubt, has a positive effect on well-being" [4, 5].

1.1 PROBLEMS WITH EXISTING SOFTWARE

A common problem with most of the existing aphasic software is that they look outdated leaving the software "associated with the 1980s by our younger clients" [4]. Existing software is also heavily drill-based and highly repetitive. Overall there is still a reliance on the users being able to motivate themselves or external pressures outside the software application itself. The software typically relies on their intrinsic motivation, that their own inability to communicate will give them the desired motivation. Most readily available aphasic software have little to none actual feedback or history of the user. This makes it difficult for the user to feel like they have made progress, providing low extrinsic motivation. The software is also based more on the old style of learning which is based upon recall while newer learning standards follow a find and use model for learning. Most have no method for therapists to monitoring the activities and results.

1.2 LEARNING AND MOTIVATION

Motivation has an important role in learning. The peak experience of intrinsic motivation is that of flow. Findings in a study of the role of extrinsic and intrinsic motivation in an internet based learning medium (ILM) found that "In short, a successful ILM should include the components of utility and fun"[6]. Furthermore the following guidelines were proposed for those developing ILM: varying the types of content, creating fun, providing immediate feedback, and encouraging interaction. Gamification has become a commonly researched area with purpose and intention of enhancing learning and driving motivation. Games are famous for capturing the attention and fully immersing it users. Successful gamification however only amplifies the existing intrinsic motivation it does not add any [7]. Extrinsic motivation, however can be created using gamification by creating competition but this must be monitored as too much competition can reduce the occurrence of a user achieving flow, as "participants are encouraged to care less about learning and participating and care more about winning" this then corresponds to the undesirable effect of being "less likely to participate without the potential of a tangible payoff" [8]. The effect of context can further improve user motivation and enhance the

1.3 AIM

The aim is to develop a computer-based application that aids in the rehabilitation of PWA and motivates them into continued use. This will be done using the real world context to increase a user's motivation with the hope of getting the users to experience flow. The software should be able to teach PWA skills that can then be easily transferred and applied in a real world context. There should also be the ability for therapists to be able to see the current progress of one of their patents and get relevant data on performance. The application will be delivered online to allow easy access and making no installation necessary. There will also be an emphasis on trying to keep the application extendable so future intelliHealth members can utilise and even extend the framework.

1.4 REPORT STRUCTURE

In order to emphasise the process and decision making during the project the report is structured to show the chronological evolution of the application. The iterations show how the application evolved throughout the process from the feedback and resulting design decisions. After an initial background research into the topic (to become familiar with the domain) a set of non-negotiable requirements were established before the first iteration of the solution began.

2.0 BACKGROUND

2.1 APHASIA

Aphasia literally means 'absence of speech' [2]. Aphasic patients "may have difficulty retrieving words and names, but the person's intelligence is basically intact"[1]. An estimated 70 percent of stroke survivors with aphasia will become depressed [9], which plays a crucial role in motivation [10].

Aphasia doesn't just have effects on the patient is has ramifications on their spouses, relatives and friends. Interestingly of note it is the spouse's "perception [of the well-being of their partner that] is important for the life situation and psychological health of the spouse" [11].

2.2 THERAPY

TABLE 1: DEFINITIONS FOR APPROACHES AND TECHNIQUES IN APHASIA REHABILITATION [12].

Approach/Technique	Definition
Cognitive neuropsychological approach	Include those that identify the underlying language impairment in terms of an information processing model of language comprehension and production. Tasks within this approach target underlying impairments.
Conversation/Interview-based assessment	Involves assessing the presence and severity of a language impairment, and the relative strengths and weaknesses in client communication skills via a conversation or interview interaction. An example of a formalized process for this approach is the Inpatient Functional Communication Interview (IFCI) [78].
CALD clients	Culturally and linguistically diverse clients.
Discourse-based treatment	Include the use of narrative, procedural, expository and conversational discourse in the assessment and treatment of communication problems. Analysis could include productivity measures (e.g. words per T-unit, Correct Information Unit), measures of cohesion, coherence and/or the overall organization of content or information.
Functional approach	Include those that focus on improving performance on everyday communicative tasks, such as buying a train ticket, shopping, asking for assistance. Communication might occur via speech, writing, drawing, gesture or symbols/pictures.
Applying principles of neuroplasticity	Involves designing interventions and setting expectations of outcome based on principles that are thought to influence brain plasticity after damage. These include the overall amount of treatment, the intensity of treatment, the phase of client recovery (acute versus chronic phases), the salience of stimuli and the schedule of feedback and practice.
Social/Life participation approach	Include those that engage the client in goal setting and therapeutic activity that is focused on their specific life participation goals and social relationships.
Stimulation approach	Include those that focus on intense auditory and visual stimulation of language functions, eliciting responses as a direct response of the stimulus (e.g. Schuell's Stimulation Approach).

There are two general categories of therapies; Impairment-based therapy and Communication-based therapy. Impairment-based therapies aim to repair "what is broken", focusing on comprehending and speaking as successfully as possible [12]. Communication-based therapies involve using any alternative means of communication, typically involves compensatory strategies and they are "encouraged to use any remaining language ability that succeeds in conveying messages" [12].

2.3 FLOW

Flow is best explained as "a phenomenon that many people find themselves experiencing when they reach a state where there becomes a perfect balance between challenge and frustration, and where the end goal becomes so clear that hindrances fall out of view" [13]. Furthermore, "While in *flow* state, the learner is completely motivated to push their skills to the limit" [13]. Flow is a much desired state for users to obtain in learning.

2.4 CONTEXT

Context in learning has been found to increases the intrinsic motivational appeal of educational activities [14]. Intrinsic motivation is more effective than extrinsic as it focuses on the subject instead of the rewards. The reason why gamification or other extrinsic motivation techniques are often utilised is because creating intrinsic motivation is difficult. Things that cause intrinsic motivation often vary from person to person. The benefit of context has been shown to give a "higher level of perceived competence" and "level of aspiration" [14]. These are benefits that are highly sought after when the rate of depression of PWA is over 70% [9].

2.5 EXISTING SOFTWARE

There is a large number of existing software for assisting with the rehabilitation of PWA. From a quick analysis of the existing aphasia software the biggest gap was in motivating their users (see our current notes in Appendix A). Most of the applications do not store any of the user's data, to extract data you could email results. This data would be for a one time performance, no long running data. It would then rely on outside assistance to analyse and motivate a user that they are improving. A lot of the software that is recommended to be used is not made specifically for PWA; it is for learning English or even learning to type. This can make it appear to be rather patronising to the user.

3.0 RISKS

The application could have no merit towards quality of life for PWA.

Creating the difficulty and gamifying the existing application can create negative impacts on a person's motivation and performance so there needs to be an understanding of the differing levels of a person's ability to interact and implied knowledge. Extrinsic motivation also needs to be made sure that it is done correctly because of its negative impacts.

Time constraints of the project could create an unpolished application that is unable to be extended.

4.0 PROCESS & TOOLS

The following are the process and tools used when developing and designing the application.

4.1 LEAN

The lean process was chosen to be used when developing the application. Lean better suits itself to discovery or unfamiliar territory, due to its fast feedback cycle and respect for validated learning. Lean works of creating an initial hypothesis, with aim to test it as quickly as possible. This stops too much design from progressing and drastic changes from occurring. The changing of a direction is called a pivot. A pivot allows for the changing of the application goal generally because the initial hypothesis has been proven false. A key component of the lean process is knowing when to pivot and ensuring that validated learning occurs. Lean embraces the term minimal viable product (MVP) for its applications allowing shortcuts and technical debt to be taken in order for the prototyping and testing to occur as early as possible.

4.2 TRELLO BOARD

An online SCRUM board was used to improve the traceability of progress and to keep the tasks on track with the overall goals and inputted an initial backlog of tasks that need to be completed (Figure 1). The cards would move across the board finally being archived after being marked done for an extended period of time. Colours were used to indicate the type of story. Epic stories were represented with red, while untasked stories using yellow .

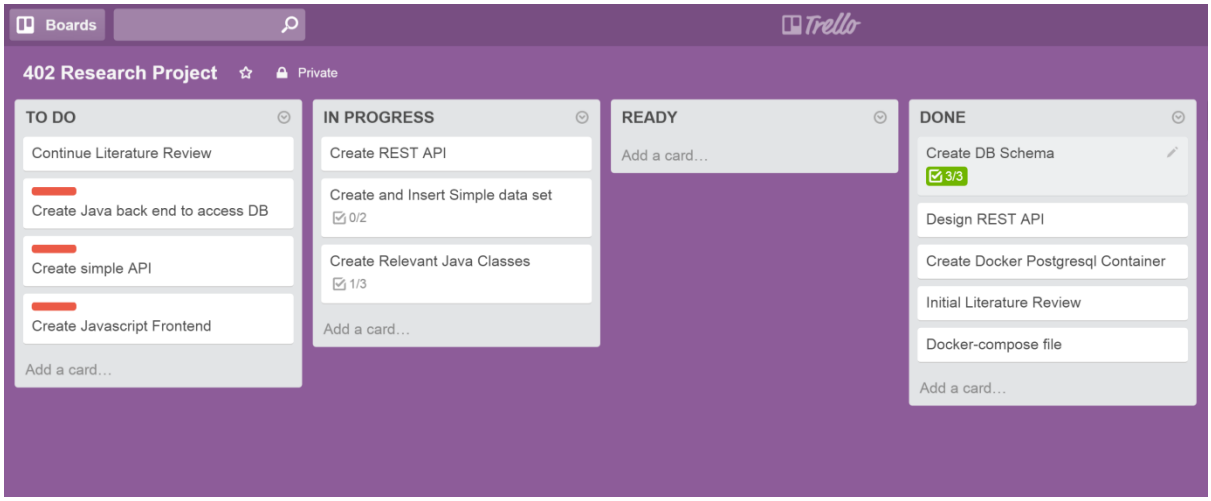

FIGURE 1: TRELLO SCRUM BOARD.

4.3 GIT REPOSITORY

A Git repository on BitBucket was used for version control. It made working on different workstations effortless and provided a backup should any system become compromised. Git was chosen due to familiarity and previous experience.

5.0 NON-NEGOTIABLE REQUIREMENTS

Due to the nature of the project there were few non-negotiable requirements that would not be subject to change or adaption. Typically these requirements come from the application's domain. Table 2 shows the three non-negotiable requirements for the project. The main theme from the requirements was a focus on accessibility.

TABLE 2: LIST OF NON-NEGOTIABLE FUNCTIONAL AND NON-FUNCTIONAL REQUIREMENTS.

F/NF	Requirements
F1	**Users can access the application using their chosen browser.** *Reason: This comes from users not wanting to install applications and allows a minimal starting effort.*
NF1	**The development environment should be portable and relatively easy to setup.** *Reason: As it will be developed and used by other members of the intelliHealth Systems Lab in the future.*
NF2	**It should be simple for others to create and add new topics and questions.** *Reason: As it will be developed and used by other members of the intelliHealth Systems Lab in the future.*

6.0 INITIAL APPLICATION DESIGN

From the non-negotiable requirements an initial architecture was chosen to be used based on previous experience. The main application was broken into the standard three part architecture, client-server-database (F1) shown in Figure 2 below.

Client: In order to satisfy browser access the client was created in JavaScript, due to its wide browser support (F1), using TypeScript. TypeScript brings static typing, improving the maintainability of the code base. AngularJS was used to control the routing and for data binding.

Server: In order to satisfy NF2 the server would need to be able to adapt to different numbers of resources and be able to serve them up to respective clients. The best way to implement this would be by creating an API that could be accessed by any client in order to use the service. The API was decided to be RESTful due to having created a REST API before in both AngularJS and NodeJS. The server was decided to be written in Java due to being more competent in the Java language. Jersey was chosen as the library due to the low barrier to entry when using JAX-RS. The application modules where controlled using maven and compiled into a war file for deployment via Tomcat.

Database: The main object-relational database management system (ORDBMS) contenders were MySQL and PostgreSQL. MySQL was available as there is an existing instance on the university system that could be used at university, However there was past experience of having used PostgreSQL before on previous projects. Using the MySQL hosted by the university would also put limitations on access and control so the use of PostgreSQL was chosen. A main difficulty with having multiple instances of databases however is keeping them in sync. To manage multiple instances and be able to work on any workstation was highly desired, Docker offers both while also being a valid release component.

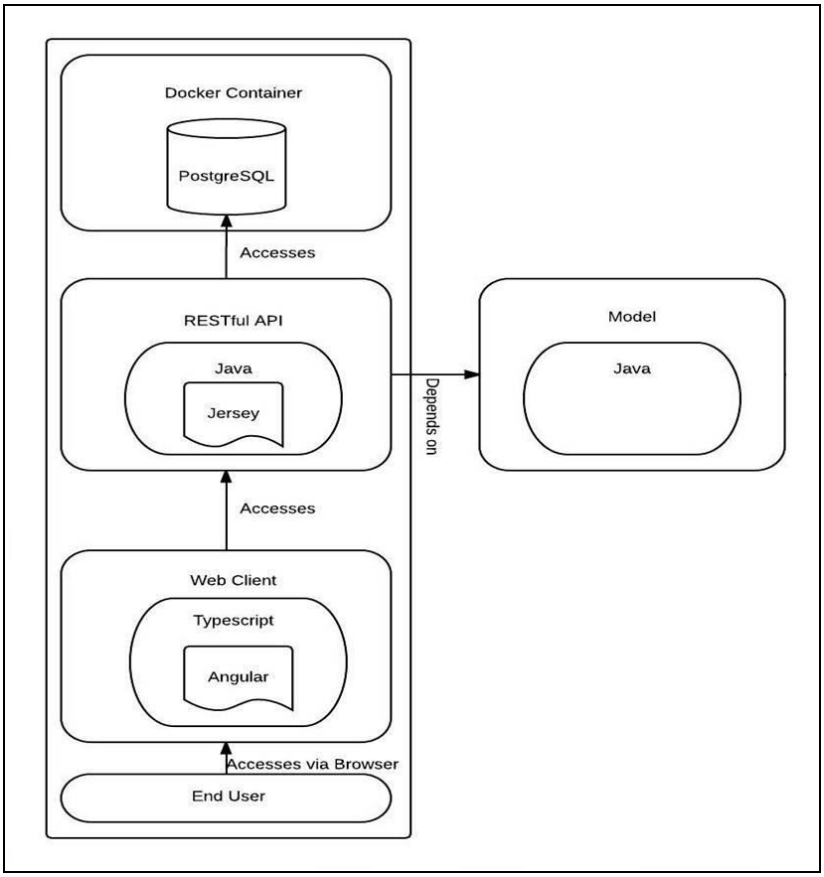

FIGURE 2: DIAGRAM SHOWING THE INITIAL TECHNOLOGY STACK.

6.1 DOCKER

Docker automates the deployment of applications inside software containers. Docker allows for a consistent environment and state, as it will always be the same state when initially launched. This is highly useful when developing applications as there are no extra costs of having to install and setup a database on every system that the application runs on. Using the Docker build file you are able to build a consistent image of the application which can then be readily launched, creating a container. With multiple images and containers that need to be orchestrated to speak to each other a docker-compose.yml file can be used to create a consistent application start up sequence, i.e. database is running before the server. The whole orchestration can then be started by the 'docker-compose up' command. Docker is open-source and leading the growing industry trend of shipping containers.

7.0 FIRST ITERATION (23 March - 8 MAY)

During the first iteration, we conducted literature research (Appendix B) into Aphasia and cognitive rehabilitation approaches and looked into the software and tools used currently for Aphasia rehabilitation. We also looked into theories in motivation and strategies used by clinicians to motivate rehabilitation. From this, we created a basic set of requirements for functionality that defines a minimal viable product (MVP).

7.1 MINIMAL VIABLE PRODUCT (MVP)

The aim throughout was to create an MVP as soon as possible so that the feasibility and initial hypothesis of the system and user feedback can be tested as early as possible. The MVP functional requirements are shown below in table 3.

TABLE 3: MVP FUNCTIONAL REQUIREMENTS.

	Functional Requirements
F2	**Users are able to choose a topic and the amount of questions to be tested.** *Reason: Being able to choose topics is common in aphasic rehabilitation software.*
F3	**Users are able to answer a question and receive the correct response.** *Reason: Basic expected functionality*
F4	**Users are able to use hints if needed.** *Reason: Common in helping prompt a user if the question alone is too difficult.*
F5	**Users are able to view their history of tests and responses.** *Reason: To allow a user to see their progression and statistics, no other reviewed application does this.*
F6	**Each user has a best "In a row".** *Reason: To motivate a user that they are doing well, beating their past selves.*
F7	**A user is given feedback on their current streak.** *Reason: To motivate the user to keep trying hard to beat their past selves.*

We also looked further into the set of system requirements in order to ascertain what would be required to develop and deploy the software system to the user within the requirements set by the MVP. This included frameworks on which the product will be delivered and frameworks in which the product will be developed. Using our set of requirements, we settled on the technical details listed below (in section 7.2).

7.2 APPLICATION DESIGN

The architecture follows the server-client-database. The RESTful API plays the role of the server interface for the client to interact with.

7.2.1 RESTFUL API

The REST service is written in Java using Jersey. Setting up the REST service took much longer than anticipated due to a lack of knowledge in creating Java web services. Table 4 defines the services to be provided in this application for the MVP. In later versions the headers will be checked for a valid authentication token before processing each request.

TABLE 4: FIRST ITERATION RESTFUL API MVP METHODS.

METHOD	URI	REQUEST DATA	RESPONSE	COMMENTS
GET	tests	-	200 OK and list of previous tests information	Used to get history of users tests (F5)
GET	tests/{id}	-	200 OK and a single in depth test information, includes responses.	Returns in-depth history of a single test (F5)
GET	topics	-	200 OK and a list of possible topics	Each topic has a max number of individual questions (F2)
GET	topics/{id}/{num of q's}	-	200 OK and tests in the topic and number chosen.	a list of full question (F2, F4)
PUT	tests/{id}/{q_id}/{response_id}		200 OK if PUT succeeds.	Updates the response for the question (F3)

7.2.2 JAVA MODEL

Created basic model of objects required by the server for processing and passing data. The following is the currently generated basic UML class diagram created from the MVP design specifications (Figure 3).

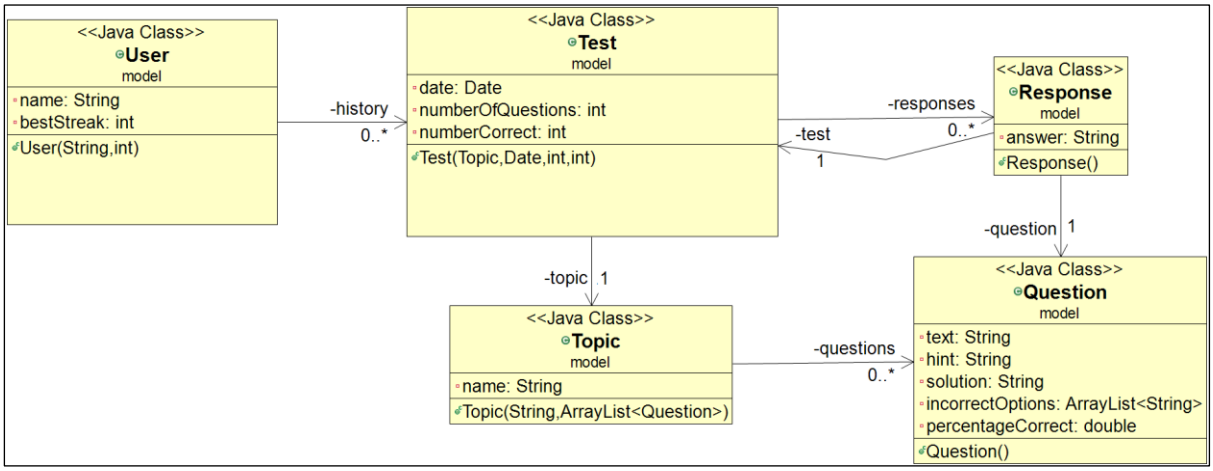

FIGURE 3: UML CLASS DIAGRAM OF CURRENT MODEL.

7.2.3 CLIENT

The client was not implemented in this iteration. This was done as the aim is to create a framework for an application rather than a UX designed solution.

7.2.4 POSTGRESQL DATABASE

The initial MVP PostgreSQL database schema was designed and created according to the MVP requirements and is attached in appendix D.

7.3 PLATFROM

This project is part of a bigger Aphasia rehabilitation project by the intelliHealth Systems Research Lab and will be developed and used by other members in future. This creates the need for a simplistic development environment. Furthermore, as we use multiple machines there needs to be a consistent database that can be setup and hosted locally for development and deployment. To conquer these challenges the database has been built in a Docker image.

7.4 ENVIRONMENT SETUP

7.4.2 DOCKER & DOCKER-COMPOSE

Setup a local boot2docker and created a Dockerfile to create images for a PostgreSQL and data container. A Database requires two containers to have persistent data due to the nature of Docker not preserving anything outside initial image state. So there is an initial PostgreSQL container that runs the PostgreSQL instance and a data container which stores the database data in its volumes (the data container is only run once) (Figure 4). To simplify the process a docker-compose YAML file is used to orchestrate the building and running of the Docker containers so that only 'docker-compose up' is needed to build and start the PostgreSQL database. The docker-compose YAML file is attached in Appendix C.

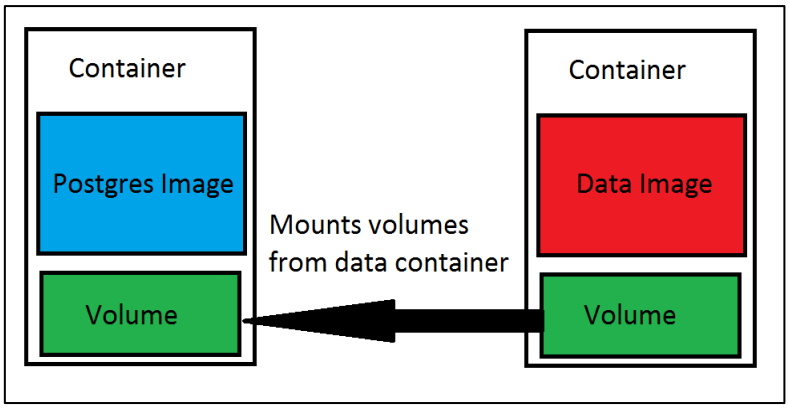

FIGURE 4: DOCKER VOLUMES-FROM EXAMPLE, BOTH ARE COLOURED THE SAME TO INDICATE SAME VOLUME.

8.0 SECOND ITERATION (8 MAY – 17 JULY)

In reviewing the work performed and application concept, after the first progress report, there was a lack of measurable differences between our concept and existing solutions. It was time to perform a pivot. The only difference was having a user history, which will not improve motivation alone. In reviewing existing solutions the most common shortcoming is the removal of context from solving a problem.

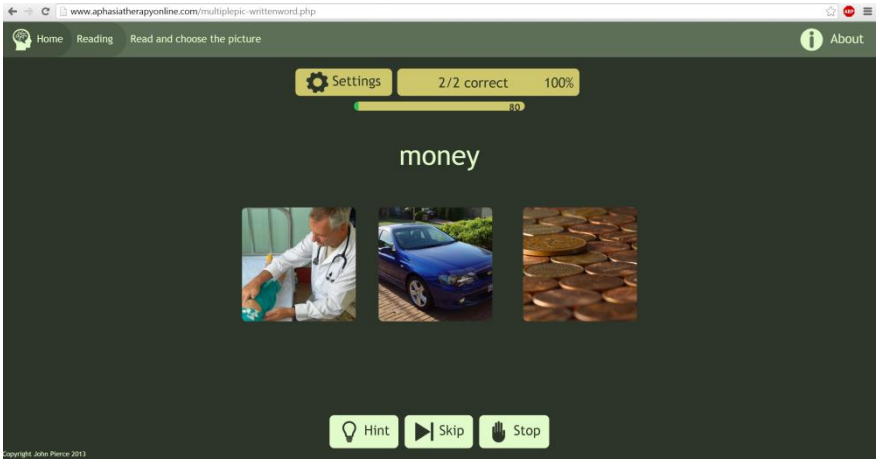

FIGURE 5: AN EXAMPLE OF THE COMMON PROBLEM STYLE FOR COMPUTER BASED THERAPY [15].

Figure 5 shows an example of a user being given the task to click on the image of "money" provided by a popular free therapy site. The problem with these and other therapy applications is in the usage of stock images. Stock images narrow the field of view and the user is presented with an image of the object cropped to fit, context removed. It creates a disparity between the learned template and real life scenarios. When faced with problems they only have one option to rely on identifying money without context and using only visual recognition. Suddenly the task of "Can you grab my money?" becomes reliant on scanning the entire room for something that matches the stock image. Furthermore it would not be often that you would ever see money as displayed in the stock photograph either. The solution is to give the user full images of real scenarios. In doing so, we can allow them to use the context of the problem to aid in recognition giving them more techniques and cues to work with. "It is well known that context plays an important role for the recognition of objects in human vision" [15].

The process could also be taken further in "story mode" to involve audio feedback and sound loops to improve the context of the image. With audio, it increases the number of cues for recognising objects in their environments.

8.1.0 PROPOSED SOLUTION

The main basis of the solution is to improve the understanding and recognition abilities of PWA towards recognising an object visual when only given the written word. To vary the difficulty proposed methods are provided below along with elements of gamification and students playing the teaching role.

8.1.1 PROBLEM TYPES:

The varying problem types currently been proposed are two different types:

- Finding an item (Image of Fridge is shown: Find the milk).
- Interpreting an Image (i.e. Is the fence locked)?

In order to vary the learning experience the aim is to provide two different modes both a story and practice mode. The story mode would set itself up as a "point and click adventure" with the aim of immersing the user throughout a series of tasks to complete an objective (i.e. Supermarket shopping, baking a cake). Practice mode would be used to target specific types of problems with their being varying options for difficulty from casual to time trial versions.

8.1.2 VARYING DIFFICULTY:

By showing the whole scene it means that the difficulty of finding the object becomes dictated by the amount of noise in the image.

- Difficulty Options
    - Optional text hint
        - Would be a simple text hint: "A white curved bottle with a handle"
    - Text hint areas
        - Displays text to the user giving feedback on the clicked zone which can encourage or give further advice about the object.
    - Area hints (blur area outside hints):
        - Blurs all the area outside of these areas eliminating a lot of noise
            - Does not mask the image as to preserve the original context.
        - Priority/Precedence?
            - Rank the hint areas so for each click one could be removed
                - Further reducing the difficulty
    - Timer to apply pressure
        - Varying starting time for initial difficulty.
        - For each correct answer the user would gain more time.

8.1.3 USER MISSIONS:

The aim of missions is to get the user to help another user by giving them a hint or technique for how they as an "expert" solved the problem. The purpose of getting the user to describe their technique is it can be useful for others be it slightly unconventional also it can allow medical practitioners to look at their patients and evaluate the mission answers so they can give constructive feedback to encourage them further.

- User is asked as now an "expert" to help another user by creating their own hint that would aide their "student" in finding the solution.
    - Varying mediums from:
        - Text
        - Visual
        - Audio
    - Varying techniques
        - Describe the object (i.e. Colour, Shape, and Texture).
        - Where it is typically found? (i.e. In the fridge door, On the bench)
        - How did you solve this?
        - Fit the solution into the given box.
        - What is the object used for?

8.1.4 FEEDBACK:

Getting feedback after providing help is an important aspect for a motivated and thriving community. The feedback can motivate users to feel like they have made a difference when they have their advice recommended or liked and achieving a number of recommendations could result in the user receiving community badges. The stored history of a user's clicks can allow a practitioner to fully review the attempts made for each problem. This data could then be used to motivate a user by showing them their improvement in both speed and accuracy over time.

- Users
    - Have the ability to recommend other user's suggestions.
    - Get the user to rank the difficulty of the problem (Ask them if they found it fun).
- Medical Practitioners
    - Review their patient's "Missions".
    - Look at their patient's data as an actual history is created and stored.
        - Speed, accuracy etc...

8.2.0 APPLICATION SCOPES

Currently two different applications have been developed which live in different spaces the first application is for PWA to interact with. As the aim is for it to be widely and easily accessible it exists as a web application.

The second is an application that medical practitioners would be able to interact with to create their own questions which could then be added to therapy. Figure 6 below is a visualisation of the overarching architecture for the two projects.

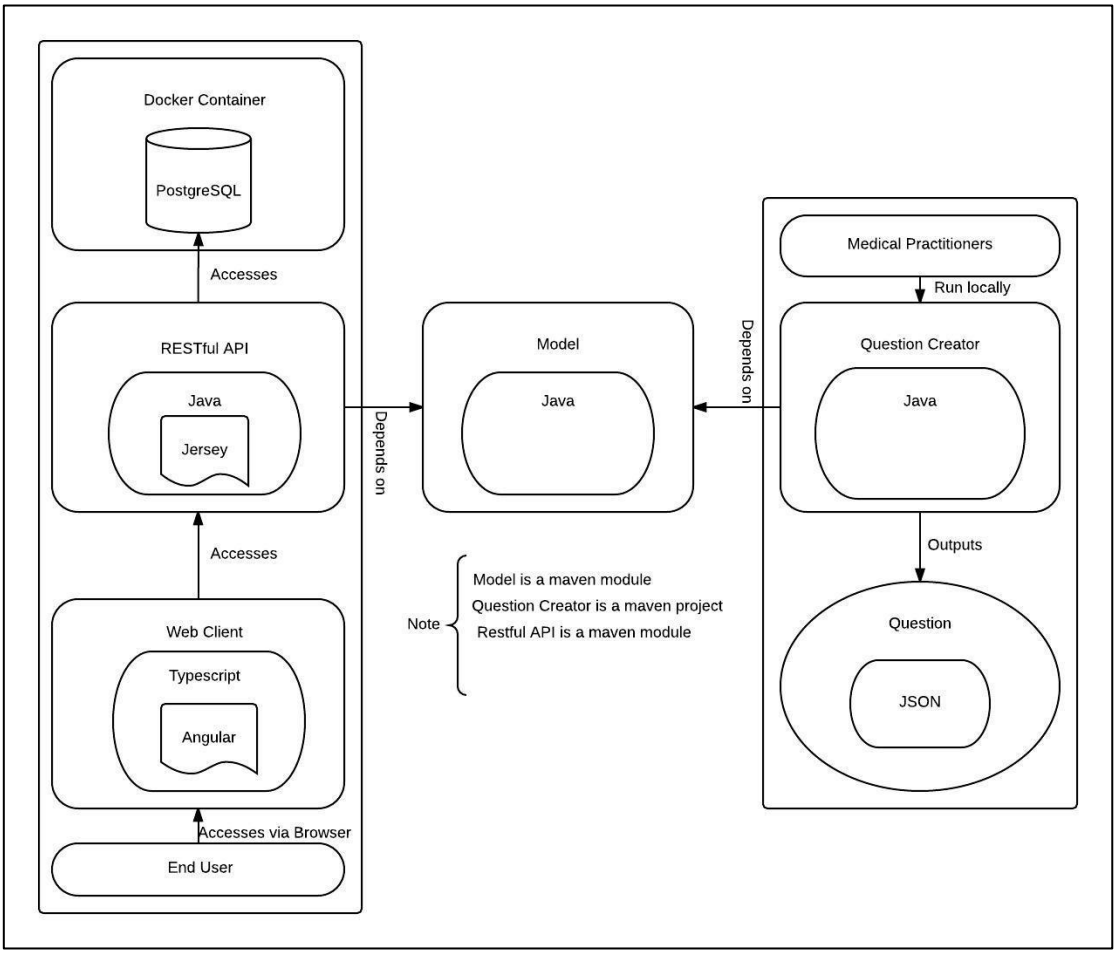

FIGURE 6: DIAGRAM OF THE CURRENTLY DESIGNED APPLICATIONS. LEFT: THE APPLICATION FOR PWA. RIGHT: THE QUESTION CREATOR TOOL FOR ALLOWING MEDICAL PRACTITIONERS TO EASILY CREATE QUESTIONS FOR USE IN THE LEFT APPLICATION.

An important step in setting up the projects was in using maven as a dependency management tool. Maven allows the use of modules to break a project into modular components that could be used as dependencies for related components without having to duplicate code. As shown in Figure 6, both the Question Creator and Restful Server depend on the model module.

8.2.1 JAVA MODEL

The model (in figure 7) has change extensively since the initial outset. This is due to the change in proposed solution and nature of an iterative development process. Each object implements JSONserializable this allows each object to be individually control how it saves and loads itself.

Testing of critical methods (i.e. saving and loading) in the format of Behaviour Driven Development (BDD) following the "Given, When, Then" format has also been conducted. Test Driven Development (TDD) was not chosen to be followed due to the large upfront cost that will transfer to waste as the project is still very much in a state of MVP and constantly evolving.

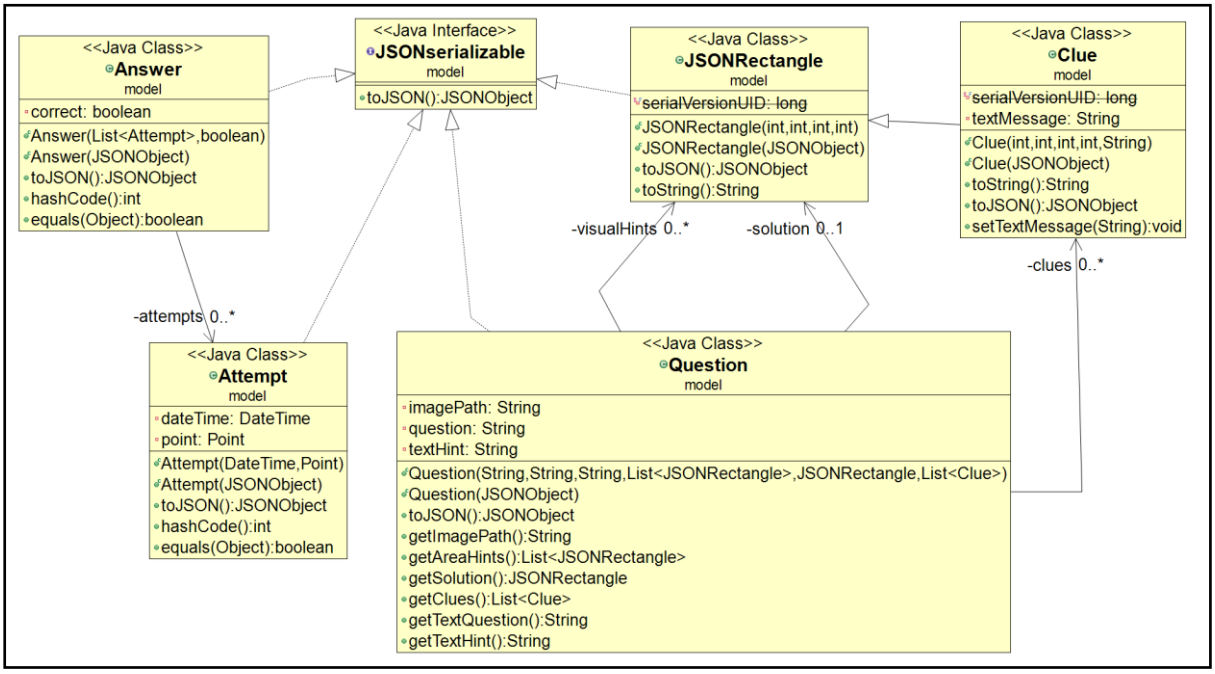

FIGURE 7: SECOND ITERATION CLASS DIAGRAM FOR THE CURRENTLY USED MODEL MODULE.

8.2.2 QUESTION CREATOR

The Question Creator is a tool built to aid medical practitioners in rapidly creating therapy questions. It is built in Java using Swing for the frontend (Figure 8) and outputs a JSON file which contains the question data. A question is made up of an image file and a JSON file. The tool provides several benefits over a manual approach:

- Faster than manual creation
  - Otherwise you would have to measure up the rectangles and manually append them to the JSON file.
- Does not require knowledge of JSON
  - Allows questions to not have to be created by developers or technically savvy people.
- Validates that the question and JSON is correctly formed.
  - Conforms to a standard.

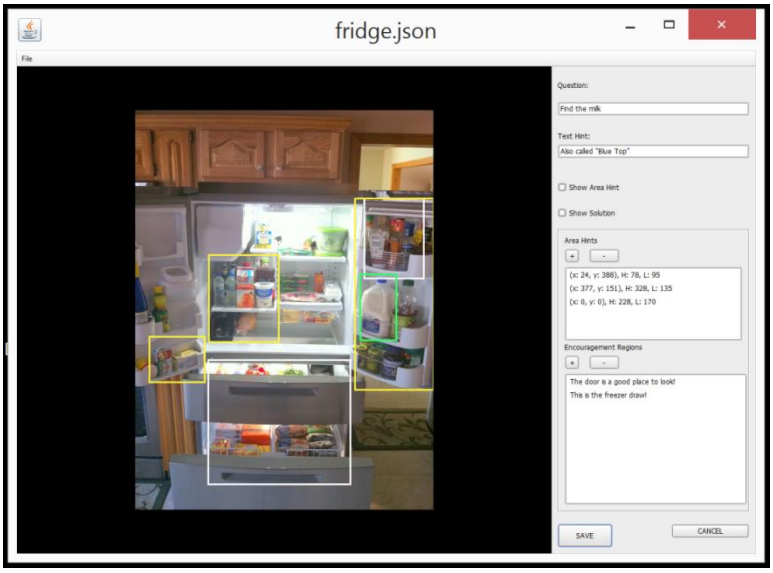

FIGURE 8: THE QUESTION CREATOR WITH A LOADED QUESTION FROM A JSON FILE [16].

In Figure 8, the white rectangles are encouragement regions, the yellow rectangles are hint areas and the green rectangle is the solution (for definitions see Varying Difficulty 8.1.2). Due to the rapid development of this tool there is an extreme coupling between the controller and the views which has brought in a level of technical debt. This debt was taken on in-order to create the tool as fast as possible. But as it is unlikely that there would need to be swap the view while leaving the controller untouched this debt is easily justified.

8.2.3 RESTFUL API

The RESTful API continued in Java using Jersey. Authorisation of requests was excluded as the requests had to be reworked to meet needs of the change in requirements. The API has a simple Question, Image and Answer service as shown in table 5. The aim is to stay simple and only adding each of the previously discussed API requests (7.2.1 Table 4) as needed.

FIGURE 9: CURRENTLY IMPLEMENTED API REQUESTS AND RESPONSES.

METHOD	URI	REQUEST DATA	RESPONSE	COMMENTS
GET	questions/{id}	-	200 OK and requested Question	Does not reply with the image.
GET	images/{id}	-	200 OK and requested Image	
POST	answers/	Answer Object	200 OK if POST succeeds.	Updates the history of attempts and User's history

8.2.4 WEB CLIENT

The client has been developed using a combination of Typescript and AngularJS. Typescript was chosen as it allows for static typing which poses a greater control of objects, methods and accessibility (as long as others use typescript). AngularJS was chosen due to past experience, having used AngularJS both commercially and in a university course.

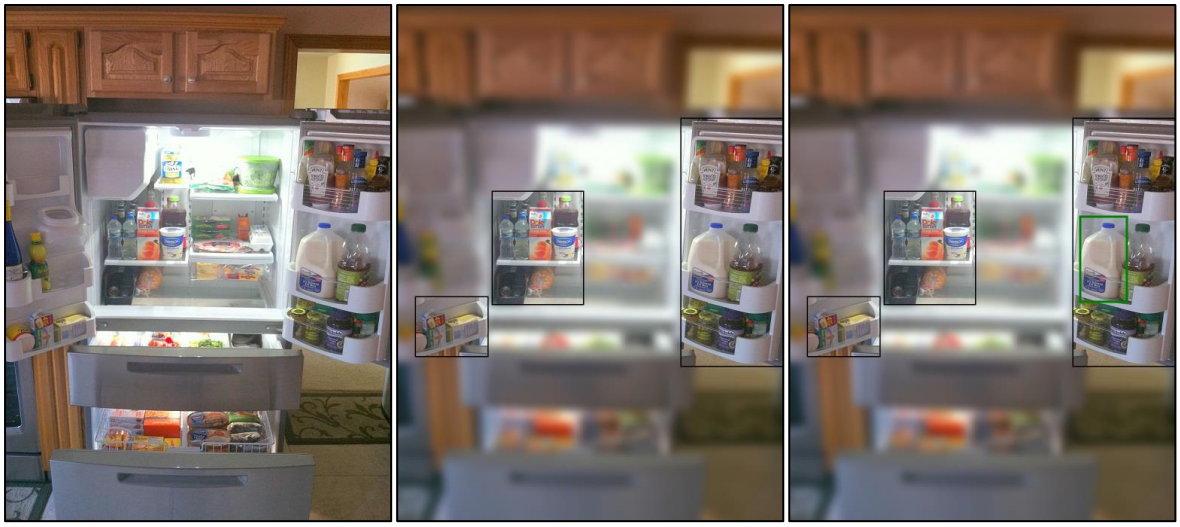

FIGURE 10: CURRENT CHANGE OF THE CANVAS. LEFT: ORIGINAL IMAGE, MIDDLE: IMAGE AFTER APPLYING AREA HINTS, RIGHT: SHOWING THE SOLUTION BOX AFTER AREA HINTS [16].

The current application is able to make a request for a question, request an image and post the answer that the client gets. Figure 10 shows the effect of currently getting 5 and 10 incorrect attempts (where area hints and the solution are shown respectively). Importantly the context is kept by simply blurring the background. The canvas registers the location of each click event (for only the canvas) and an attempt object is created with a point and timestamp which increments the current number of attempts. The answer is then posted to the REST API.

The application currently uses two non-standard libraries:

- StackBlur.js
  - For performing the visual blur of the images
  - Fast library – Open Source
    - Performs a pseudo-Gaussian blur
    - Blurs the image to be drawn on the canvas
- HeatMap.js
  - For showing where a user has clicked on the image.
    - Can also be used to show clicking trends.
  - Open Source
    - Widely used for heat mapping (FIFA, GPS Visualisation etc..)
    - Takes up to 40,000 points
      - Involves grouping points upon being posted to the API.

8.3 VALIDATED LEARNING

8.3.1 ECLIPSE DEPLOYING DEPENDENCIES TO WEB SERVER

1. Eclipse will offer the ability to auto deploy the code on its own web server
2. However it would continuously fail to load the model dependencies
3. Checked build target and it has dependencies
4. Turns out it gets ignored for copying to web server
5. Have to manually add the model.jar to the web servers files

8.3.2 CORS

1. Web Client is unable to get response from API due to browser XSS restrictions
2. Had to add Access-Control-Allow-Origin headers to API response "*" and Methods "GET, POST, OPTIONS"
3. Created CORS Filter for Jersey to run all requests through attaching the appropriate headers.

8.3.3 GIT RESET –-HARD

1. Added files (accidentally made it an .hgignore not a .gitignore).
2. Realised so did the normal reset "git reset –hard"
3. Realised that reset cleans by removing added files that have never previously been checked in.
4. Had to run "`git fsck --no-reflogs --lost-found`" command to generate lost and found
5. Scan through lost and found files then rebuilt the Question Creator project from recovered files.

9.0 THIRD ITERATION

The third iteration involved progressing from an MVP towards a scalable and dynamic solution. As the previous two iterations had created a reasonable level of technical debt in the application extra work was required when adding new features. The main areas of debt where the hardcoded values for the client and hard coded responses from the API.

9.1 JAVA MODEL

The model is changed further to keep up with the evolving features. The model for representing the answer and questions where updating to be insert into the PostgreSQL database. Shown in figure 11, there have been many methods added to handle the inserting and building of objects from the database. The answer class was fleshed out further to hold information about the user and the related question id.

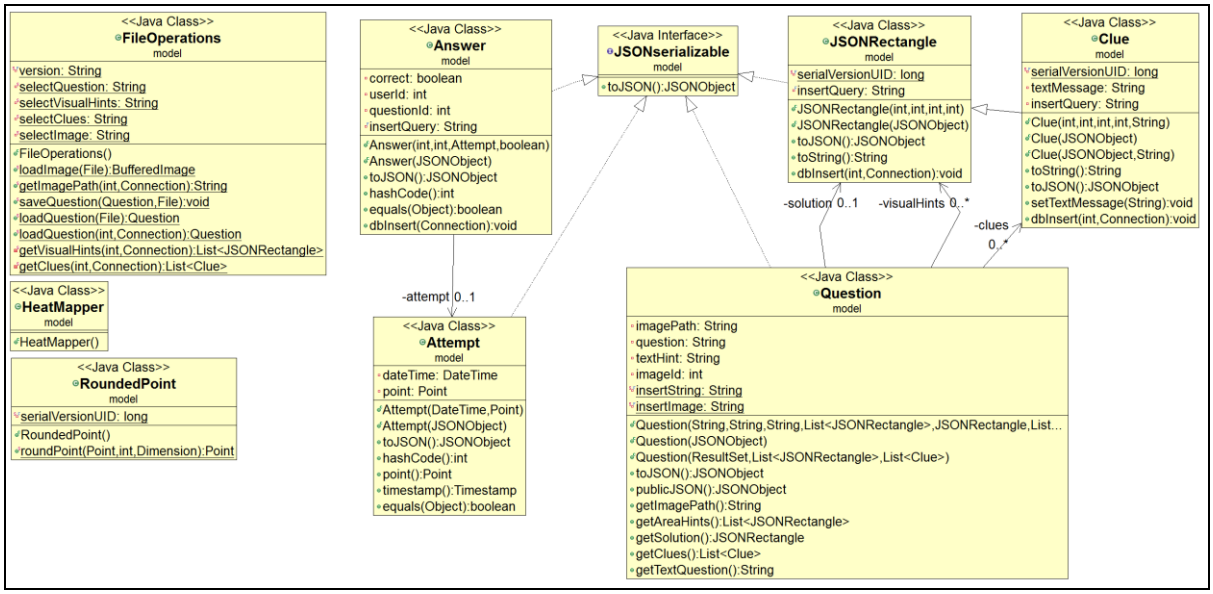

FIGURE 11: THIRD ITERATION UML CLASS DIAGRAM OF THE CURRENT JAVA MODEL.

9.2 POSTGRESQL DATABASE

The PostgreSQL database was updated to match the change since the first iteration. During the second iteration no database was used, (as previously stated) this created an element of technical debt. The technical debt increased the amount of effort to turn the API calls from loading a set text file to grabbing a connection to the database, performing a query, and building the returning object. The updated database schema is in Appendix E.

9.3 DATABASE CONNECTION POOLING (DBCP)

In order to address the issue of serving multiple users concurrently DBCP was implemented. A DBCP creates and handles the lifecycle of connections allowing you to interact as if there is only a single connection where the DBCP instead of closing frees the connection to be used and puts it back into the pool. This stops the cost of creating and closing connections and removes the hassle of manually scheduling connections. There is a wide selection of DBCP tools, however HikariCP is currently the leading tool as it is the fastest reliable connection pool available as shown in figure 12 below.

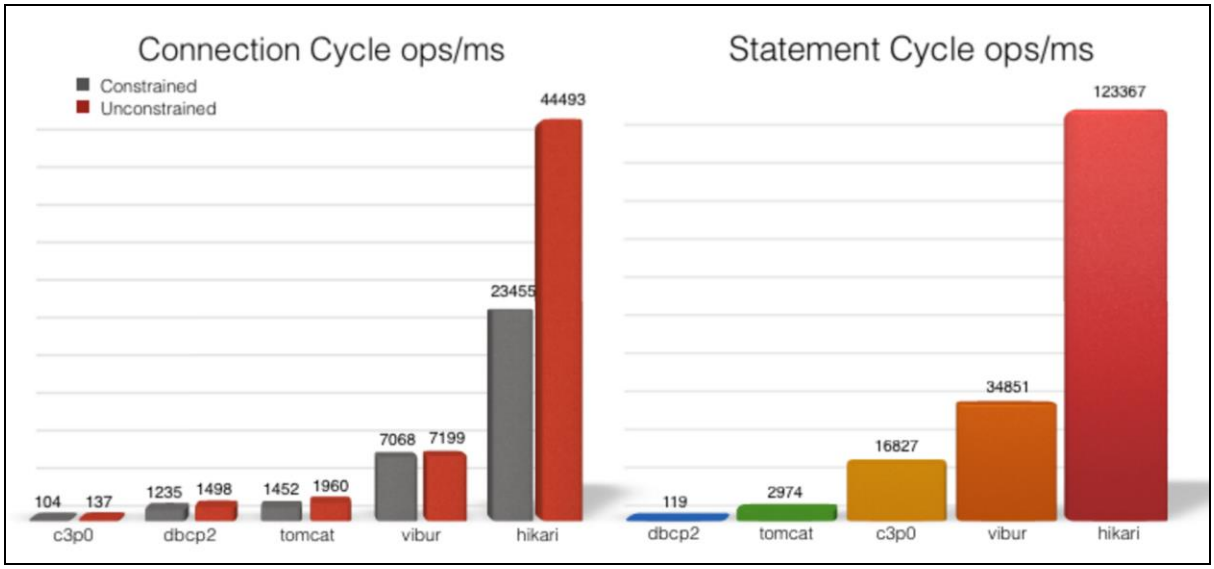

FIGURE 12: SHOWS THE PERFORMANCE OF HIKARICP COMPARED TO COMPETING DBCPS [19]

9.4 RESTFUL API

The RESTful API is extended further as new methods had to be added to incorporate the dynamic updating of questions for loading added ones to the server and requesting a list. The RESTful API has the following implemented calls (Table 5).

TABLE 5: SHOWING THE CURRENT AVAILABLE API CALLS.

METHOD	URI	REQUEST DATA	RESPONSE	COMMENTS
GET	questions/	-	200 OK and request list of question text + id	Replies with an object with a single list of questions and ids.
GET	questions/{id}	-	200 OK and requested Question	Does not reply with the image.
GET	images/{id}	-	200 OK and requested Image	
POST	answers/	Answer Object	200 OK if POST succeeds.	Updates the history of attempts and User's history
POST	update/questions	-	200 OK if POST succeeds	Updates the questions by loading local files into the database if not already added.

9.4.1 TECHNICAL DEBT:

The "update/questions" is a bad design as is the answers/ request calls. The reason is that they violate the common standard for API calls. The update/questions should be a POST to questions/ instead but the class was implemented rapidly and still could easily be moved to the correct class. The answers/ method should be changed to answers/{question_id} as the usage answers/ also violates REST design standards. I should also not post the user_id inside the answer as there is already an authorization token declaring whom the user is.

9.5 SECURITY

As the application has reached a reasonable level of stability in this iteration a basic set of security was implemented. The security concerns when inserting into the PostgreSQL database and information being sent to the client was addressed in a simplistic form.

9.5.1 CLIENT AUTHORIZATION

The client side authorization simply takes in a username. This is because no protection is currently used for storing passwords so it is better to start with a basic username removing the possibility for their password being leaked. The client current checks if the name is valid, it does this without checking against the server currently. It just hardcoded checks if the name is 'test'. If the user tries to access any page without being authorized they are immediately re-routed to the login page before any resources are loaded. This authorization could easily be extended to check with the server by changing the authorization method that gets called when checking creating a simple single point for extending the current security.

9.5.2 SERVER AUTHORIZATION

The server authorization was implemented by creating an authorization annotation (Figure 13). The annotation '@Authenticated' could then be used above a RESTful service to state that the user must be authorized to perform the request. Before processing a request, the request is checked for an authorization token in the header called 'token'. Currently no check is conducted that the token is valid but it creates a single point of extension for creating an authorisation service. If the token is invalid then an unauthorized response is replied.

```
@Target({ ElementType.TYPE, ElementType.METHOD })
@Retention(value = RetentionPolicy.RUNTIME)
@NameBinding
public @interface Authenticated { }
```

FIGURE 13: CODE SNIPPET SHOWING THE AUTHENTICATED INTERFACE ANNOTATION.

9.5.3 PREPARED STATEMENTS

In order to mitigate the risk of SQL injection the insertion of objects into the database was conducted using prepared statements as shown in figure 14. Using prepared statements limits the attack surface for an attacker. Also separates the command from the content limiting the ability to escape the string to run a malicious query.

```
preparedStatement = connection.prepareStatement(insertString, Statement.RETURN_GENERATED_KEYS);
preparedStatement.setString(1, this.question);
preparedStatement.setString(2, this.textHint);
preparedStatement.setString(3, this.solution.toJSON().toJSONString());
preparedStatement.setString(4, filePath);
preparedStatement.setInt(5, this.imageId);
```

FIGURE 14: CODE SNIPPET SHOWING THE USAGE OF PREPARED STATEMENTS, GETTING BACK THE IDS OF OBJECTS INSERTED.

9.5.4 JSON MODEL

The model was previously exposing confidential information to the client that could be extremely valuable to an attacker. When requesting a question the client was being sent an internal file path to an image. This could inform an attacker of the operating system that the service is being run on, the username, and the directory structure. From here an attacker could attempt to load private images or login as the username discovered. To avoid exposing data, the question was updated to be sent to the client with the id of the image in the database instead of the file path, vastly reducing the amount of public image displayed.

9.6 SENDING ATTEMPTS

Each individual attempt on a question is sent to the server. This was done to make it more difficult for a user to cheat the system by guessing until correct and reloading the page to get it in a single try. Sending each attempt reinforces the requirement for the DBCP, putting further emphasis on making sure connections don't block the database.

9.7 VALIDATED LEARNING:

9.7.1 DOCKER ENGINE UPDATE

1. New Docker Engine was released (1.8.1)
2. This caused issues with the way that Docker-compose was executed on windows
3. By upgrading without checking if the version was stable it meant that the database was unable to be run for a period of time.
4. Fixed eventually by Docker Toolbox #221 (https://github.com/docker/toolbox/pull/221)
5. Patched to 1.8.3
6. Learnt to check the bug tickets before blindly upgrading.

9.7.2 BUILDING TO META-INF

1. Context.xml file is required when specifying tomcat resources and lives in META-INF.
2. Was getting failure to locate HikariCP drivers from the tomcat server. "java.sql.SQLException: Cannot create JDBC driver of class '' for connect URL 'null'"
3. Found out it was due to Context.xml be put into the WEB-INF folder.
4. Followed the answer from a stackoverflow question to make the resource folder build to the correct folder.(http://stackoverflow.com/questions/13701300/maven-webapp-meta-inf-context-xml)

10.0 LIMITATIONS

The following are design limitations either from decisions made deliberately or accidentally. Some limitations also occur due to failing to implement a feature to get around a problem due to prioritisation of features.

10.1 CREATING USERS

Currently user creation is completely reliant on being conducted by a DBA. This is fine due to the applications small beginnings but for the application to become truly scalable it would need to be rectified as it could quickly become overwhelming.

10.2 SINGLE QUESTIONS

The application uses single questions only in its current form; there has been no implementation of topics or grouping of questions to create tests. Creating Topics or tests would require additions to the model, database, and restful service.

10.3 CURRENT QUESTION FOLDER

The question folder is hard coded into the source code. The problem with this is that it has to be recompiled to run the RESTful server on different computers. The question folder being hardcoded came from the second iterations implementation of loading and saving questions. This was unable to be fixed in the final iteration due to it being a low priority in comparison to adding further features. For further extensibility the folder should be changed to be relative to the directory that the application is in.

10.4 TYPESCRIPT BUILT AS VISUAL STUDIO SOLUTION

The client is built using TypeScript in a visual studio project. The problem is that in-order to use other operating systems (or to avoid visual studio) a grunt file needs to be created. This was a low priority to fixing as all of the developing environments used were on windows.

10.5 TYPESCRIPT MODEL & SERVER MODEL

The two models for the frontend and the server need to be kept compatible. As this was a single member project there was no integration tests for check-ins or CIs used. Moving forward if the number of project members was to increase then at the minimum integration test would need to be created and run locally before checking into the revision control.

10.6 IMAGE DUPLICATION IN DATABASE

There is no check for inserting a question image if the question image already exists in the database. This could be implemented using a simple select on the filepath before inserting to check that the file has not been added. This was not conducted due to time constraints and the current cost of duplicating images in the database being extremely low, as it is only two records with the exact same file path string.

11.0 FUTURE WORK

11.1 USER HISTORY ANALYSIS

Currently there is little analysis of the data that is gathered from the attempts. Using the gathered data trends could be calculated to be presented to users and their physicians (who would have accounts for monitoring their patients). Utilising the history of speed, and accuracy feedback could be improved. There is also the potential to connect the application up to ASPIRE. Utilising ASPIRE as an intelligent tutor to further personalise the feedback and difficulty from the user history.

11.2 STORY MODE

This mode would be a completely different experience to any existing aphasia rehabilitation focused software. The aim would be to use the features of point and click adventures to tell an immersive story that forces the user to complete different tasks and navigate various social interactions. Would be an un-explored field for future work and provide interesting investigation into the effectiveness of audio cues and a contextual narrative.

11.3 USER MISSIONS

User missions are an expansion upon getting users to teach each other and to create a badge based gamification to create positive extrinsic motivation. This was discussed in section 8.1.3 in detail. Implementing and studying the effectiveness and ability for PWA to aid each other would be a new frontier of research.

11.4 DOCKERIZE WAR AND APACHE INTO IMAGE

By creating a Docker build process in amongst the Docker-compose yaml file you would be able to test the code before releasing. Dockerizing the image allows the exact same application to be put through all integration and unit tests without having to then re-compile for each deployment. It means the same application that was tested is deployed guaranteeing the state. This also would aid in the development consistency as it would no-longer require the user to move files into their local apache server and would enable the rapid and consistent setup of their development environment.

11.5 DOCUMENT API

The API should become documented as it stabilizes. It currently has not been documented as the toxicity of the implementation was high enough that the amount of effort would not bring value to the application more than adding an extra feature. Also the features would often change the API, often both the object it receives and sends. Documenting the API is also a critical step in making the framework consistent and extensible.

12.0 CONCLUSION

This project followed a lean iterative development to attempt to create a novel application framework and question creation tool. The following of the lean process was practical due to the exploratory nature of the domain and requirements given. The solution required a pivot after the first iteration. The final solution aimed at improving intrinsic motivation in PWA by using the context of an object in real photographs to aid in object recognition and empowerment. The question creation tool was built in Java using swing and allows medical practitioners to quickly create personalised content for their patients which can be easily deployed to the running application server (NF2). The application was built using Java and Jersey complying with JAX-RS to implement a RESTful API which uses a PostgreSQL database. The client was created using AngularJS and TypeScript to create a browser based frontend to the RESTful API, satisfying R1. The use of Docker to create a consistent database for developing allowed a portable development environment that is simplistic to setup meeting the NF1. Overall the solution satisfies the non-negotiable requirements and has grown to provide a novel and practical solution to the problem of motivation. Due to the scope of the timeframe of the application it has achieved a reasonable result with an ability to scale using HikariCP and has been designed such that members of intelliHealth could finish and extend the application.

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Appendix A

NOTES ON EXISTING APHASIA SOFTWARE

PARROTSOFTWARE : HTTP://WWW.PARROTSOFTWARE.COM/

Massive list of Categories that you can practice.

- Functional Skills
- Cognitive Reasoning
- Memory and Attention
- Personal Programs
- Reading
- Vocabulary and Grammar
- Word Recall
- Speech Recognition

Website is bland. Uses neutral colouring. There is a clear instructions tab when conducting an exercise which informs how to interact and answer the question, explains the task. Makes noise in response to correct or wrong answer. Old UI. Not fun / engaging at all. Not an aphasia specific programme. $25.00 a month.

TACTUS THERAPY : HTTP://TACTUSTHERAPY.COM/

Specifically targeting aphasia. Offers a large selection of mobile applications. Most only available for iOS. Costs $80.00. Looks modern until you actually launch the application. Is fairly standard.

Naming
You could select a topic. It would then show an image, the user would then have progressive hints that they could use to get the answer. Which they would say aloud obviously with a partner and then tick if they got it right or wrong. (No difficulty)

Comprehension & Reading
(No difficulty)

Writing
Had 3 levels of difficulty – hard to know if you were ready to move difficulty.

There were no tutorials. It was a little ambiguous at first. A lot it suffered from saying it was correct if you didn't CUE but then how can they confirm that they are right if there is no CUE? Means it cannot be conducted individually.

There is no difference between getting wrong and getting it right after taking a hint. Very linear grading. Very Repetitive. No feedback to the actual user, no extrinsic motivation, no past scores (unless emailed – they are not stored on the device to prompt you). Correct answers were greeted by a chime. You could see your current score in the top right hand corner. Upon completing a task you could then EMAIL the results to someone. Also would rate any cue as wrong. Very linear scaling of what is right and wrong. Not fun or engaging.

APHASIA THERAPY ONLINE : HTTP://WWW.APHASIATHERAPYONLINE.COM/

Specifically targets Aphasia. Email results. It is free. Has listening, reading, spelling and naming modules. Follows the standard learning model. Has a modern UI.

Doesn't give answer as correct if hint is taken, upon completion shows data correct with hints, correct without hints, and incorrect. It does not store any of your previous scores and also makes a small chime when the answer is correct. Upon an incorrect answer it makes an incorrect chime and then repeats the question and selects the correct answer.

Still no history of user's scores. Can be done mostly individually. No increased motivation. Not fun or engaging.

FIRST KEYS 3 : HTTP://WWW.WIDGIT.COM/PRODUCTS/FIRSTKEYS3/

Not built for aphasia, is for teaching typing on the keyboard/spelling. It costs 59 pounds. Overly customizable, doesn't have any difficulty curve to inform the user if they should move up. Has past statistics but they are only in graphs. Doesn't use the statistics to motivate the user. The user has to setup the environment and manually change difficulties. Difficult to navigate. Has a UI from the early 90's. Windows only application. Congratulates the user upon a correct answer, both in text and audibly.

Appendix B

LITERATURE RESEARCH NOTES

Paper: Using Mobile Technology with Individuals with Aphasia: Native iPad Features and Everyday Apps.
Author/s: Szabo, Gretchen; Dittelman, Janice.
Process: Taught sufferers of Aphasia how to use and operate ipads at a basic level. They were also taught how to use some native apps.
Outcome: Most users learnt how to operate the ipad adeptly, found that PWA used Calendar to store information to help aid their memory struggles. Also were able to use existing aphasia apps to aid their everyday lives.
Interpretation: PWAs are able to learn to use and operate new technology even without any previous experience (pre-condition). An interesting result was "As members throughout the center began to observe their friends using the iPads, it sparked more interest and curiosity, eventually resulting in waiting lists for the technology group and laboratories".
Topics: Computer Rehabilitation.

Paper: How to Use Apps Clinically in the Treatment of Aphasia
Author/s: Holland, AL; Weinberg, P; Dittelman, J.
Process: First ascertain if the client has achieved "Buy-In" criteria.
Topics: Computer Rehabilitation**,** Clinical Selection.

Paper: Steps to Success with Technology for Individuals with Aphasia.
Author/s: McCall, D.
Process: The current study investigated the effectiveness of a home practice program based on the iPad (Apple Inc., Cupertino, CA), implemented after 2 weeks of intensive language therapy, for maintaining and augmenting treatment gains in people with chronic poststroke aphasia.
Outcome: The current study, along with others in this special issue, are meant to contribute toward forging a path in creating an evidence base for independent HP using tablet devices.
Topics: Computer Rehabilitation.

Paper: Accessibility of Computer Therapy and Technology for People with Aphasia
Author/s: Roper, Abi.
Process: The described project aims to examine general technology access and confidence in users with aphasia.
Topics: Computer Rehabilitation.

Paper: Mobile computing technology and aphasia: An integrated review of accessibility and potential uses.
Author/s: Brandenburgab, Caitlin; Worrallab, Linda; Rodriguezabc, Amy D; Copland, David.
Conclusion: Improving access to mobile computing technology by people with aphasia has the potential for enhancing both social participation and management of aphasia. It is clear from this review that more research is needed into how accessibility may be improved, as well as on the development of mobile applications that aid management of aphasia.
Topics: Computer Rehabilitation

Paper: A comparison of aphasia therapy outcomes before and after a Very Early Rehabilitation programme following stroke.
Author/s: Godecke, E; Ciccone, NA; Granger, AS; Rai, T; West, D; Cream, A; Cartwright, J; Hankey, GJ.
Conclusion: A prescribed, impairment-based aphasia therapy regimen, provided daily in very early post-stroke recovery, resulted in significantly greater communication gains in people with mild–severe aphasia at completion of therapy and at 6 months, when compared with a historical control cohort.
Topics: Computer Rehabilitation, Therapy session Intensity.

Paper: Aphasia LIFT: Exploratory investigation of an intensive comprehensive aphasia programme
Author/s: Rodriguez, Amy D; Worrall, Linda; Brown, Kyla; Grohn, Brooke; McKinnon, Eril; Pearson, Charlene; Van Hees, Sophia; Roxbury, Tracy; Cornwell, Petrea; MacDonald, Anna.
Conclusion: Computer-based treatment can be used to increase the amount of treatment provided with the added benefit of promoting independence and increasing self-worth.
Topics: Therapy session Intensity.

Paper: Editorial Computers and aphasia: A means of delivery and a delivery of means
Author/s: Petheram, Brian.
Topics: Computer Rehabilitation, Therapy session Intensity.

Paper: Computers in the Treatment of Chronic Aphasia
Author/s: Katz, RC.
Topics: Computer Rehabilitation

Paper: Virtual Rehabilitation Environment Using Principles of Intrinsic Motivation and Game Design
Author/s: Mihelj, Matjaz; Novak, Domen; Milavec, Maja; Ziherl, Jaka; Olenšek, Andrej; Munih, Marko.
Topics: Motivation, Gamification

Paper: Design strategies to improve patient motivation during robot-aided rehabilitation
Author/s: Colombo, R; Pisano, F; Mazzone, A; Delconte, C; Micera, S; Chiara Carrozza, M; Dario, P; Minuco G.
Topics: Motivation, Computer Rehabilitation

Paper: Gamifying learning experiences: Practical implications and outcomes
Author/s: Domínguez, Adrián; Saenz-de-Navarrete, Joseba; De-Marcos, Luis; Fernández-Sanz, Luis; Pagés, Carmen; Martínez-Herráiz, José-Javier.
Conclusions: Gamification in e-learning platforms seems to have potential to increase student motivation, but it’s not trivial to achieve that effect, and a big effort is required in the design and implementation of the experience for it to be fully motivating for participants.
Topics: Gamification, Motivation

Paper: Gamification: metacognitive scaffolding towards long term goals?
Author/s: Ming Tang, Li; Kay, Judy.
Conclusions: Gamified Metacognitive Scaffolding: Self monitoring and reflection, Planning and strategy, Self evaluation and assessment, Collaboration and Group dynamics, Game Aesthetics.
Topics: Gamification

Paper: Raising engagement in e-learning through gamification
Author/s: Muntean, CI.
Conclusion: Gamification does not imply creating a game. It means makes education more fun and engaging, without undermining its credibility. Gamification helps students gain motivation towards studying, and because of the positive feedback they get pushed forwards and become more interested and stimulated to learn.
Topics: Gamification, Motivation.

Paper: A User-Centered Theoretical Framework for Meaningful Gamification
Author/s: Nicholson, S.
Conclusion: Meaningful gamification focuses on introducing elements of play instead of elements of scoring.
Topics: Gamification.

Paper: Studying Gamification: The Effect of Rewards and Incentives on Motivation.
Author/s: Richter, G; Raban, DR; Rafaeli, S.
Conclusion: Has table of interesting evaluations of real examples using gamification.
Topics: Gamification, Motivation.

Paper: Does Gamification Work? — A Literature Review of Empirical Studies on Gamification
Author/s: Hamari, J; Koivisto, J; Sarsa, H.
Conclusion: The appendix has a table of "Studied motivational affordances and psychological/behavioral outcomes".
Topics: Gamification, Behaviour.

Paper: Two Paths to Motivation through Game Design Elements: Reward-Based Gamification and Meaningful Gamification
Author/s: Nicholson, S.
Topics: Motivation, Gamification.

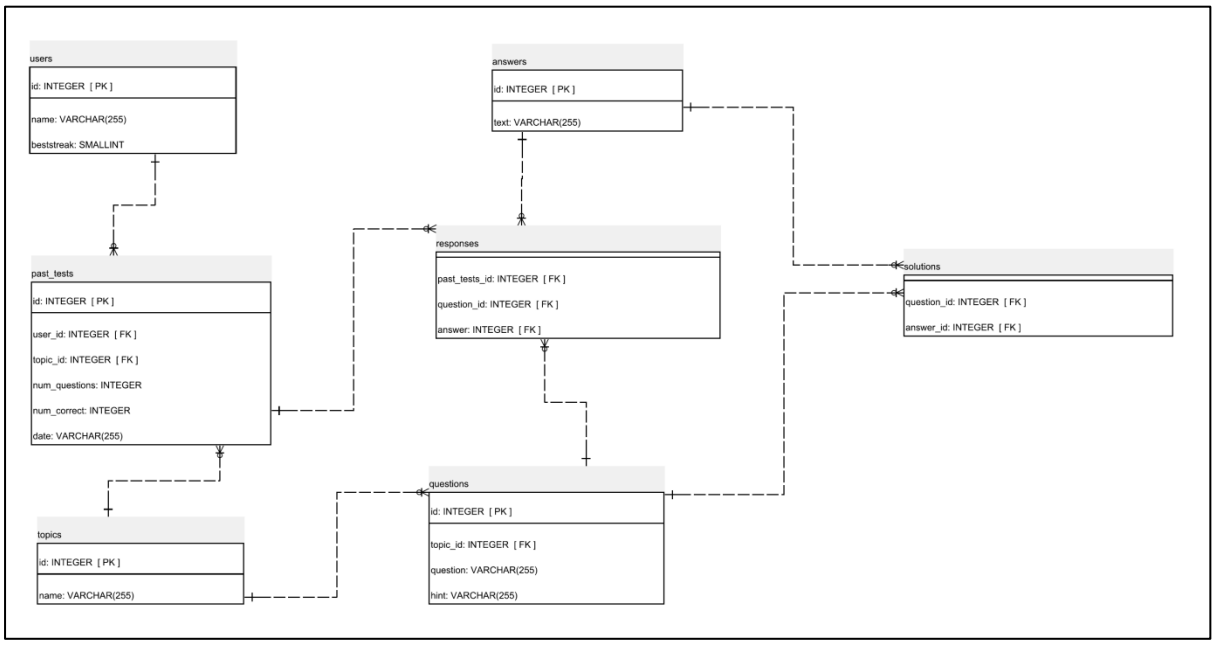
Appendix C

DOCKER-COMPOSE YAML FILE

```
postgres:
  build: postgres/postgres/.
  ports:
    - "5432:5432"
  volumes_from:
    - data
data:
  build: postgres/data/.
```

Appendix D

FIRST ITERATION POSTGRESQL DATABASE SCHEMA



Appendix E

THIRD ITERATION POSTGRESQL DATABASE SCHEMA