User Modeling and Personalisation in Search for People with Autism

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Abstract

The current proposal presents my objective to research and build a user model and web application for individuals on the Autism Spectrum within Search. The model will be built around the core features of Autism. The model will be applied to results returned from a synthesis of three leading existing search engines. The web application will be integrated with motion-controlled user interfaces (UI). The project will provide novel insights into the needs and wants of individuals with Autism within search, and enable future development and interventions within these information streams and communication channels.

*This proposal is substantially the result of my own work, expressed in my own words, except where explicitly indicated in the text. I give my permission for it to be submitted to the JISC Plagiarism Detection Service.

1 Abbreviations

API	Application Programming Interface
ASD	Autism Spectrum Disorder
DSM	Diagnostic and Statistical Manual
GCS	Google Custom Search
HCI	Human Computer Interaction
JSON	JavaScript Object Notation
KWIC	Key Word In Context
TDD	Test Driven Development
UI	User Interface
UX	User Experience
VR	Virtual Reality

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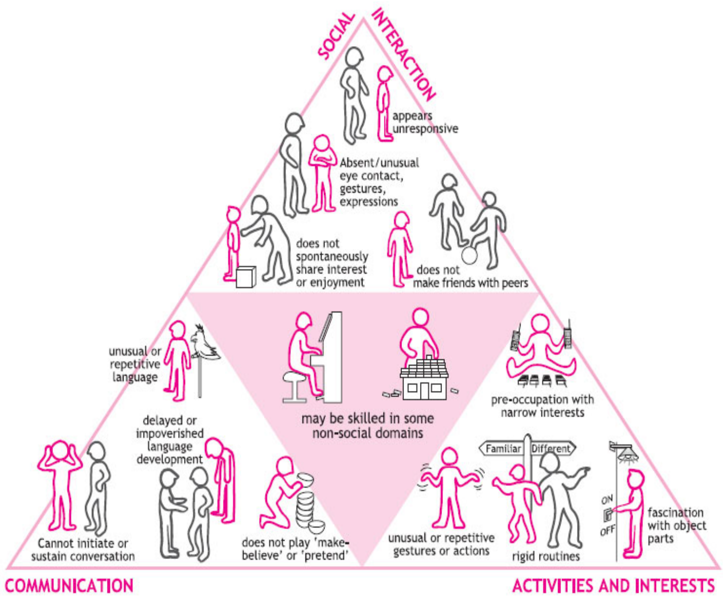
2 Introduction & Background

2.1 Problem Statement

Most search engines apply user models to refine user search queries. These models can often lack specificity for users/groups of users [2]. Although adaptive search engines have now become prominent (using search history, locale, and demographics to guess the user's intentions) these models make several a priori assumptions about users from specific subgroups. Based on the Psychology literature, general user models and the needs of the user with Autism differ. To address this issue, the current project aims to build a user model within Search for individuals with Autism. As it is well established that individuals with Autism are more engaged when using technology that is receptive and interactive (e.g., games, responsive consoles, motion controlled devices) compared to technology that is not [3], this project will combine interactive, motion recognition hardware with Search to also improve the UI (user interface) of Search for individuals with Autism.

2.2 What is the Autism Spectrum?

Autism is amongst the most common neurodevelopmental condition and it is currently estimated that 1/68 children meet criteria for Autism Spectrum (CDC, 2014). Autism is five times more common amongst boys than girls (1/42 boys, and 1/189 girls). According to the DSM-V (2013) diagnostic manual, Autism is characterized by persistent and early deficits in reciprocal social interaction and repetitive behaviours. Individuals vary from high functioning to low functioning (along a spectrum), with behaviours emerging around 2 to 3 years of age.



The Autism Triad [12]

2.3 The Role of Context In Search

It is unlikely that any given page on the web will contain a word or phrase that means exactly (or nearly) the same as another word or phrase in that language (e.g., shut and close). How is it then that your search engine picks these phrases to mean the same thing, and returns them synonymously in the results of your query? Well, quite simply put, it is by virtue of the fact that

each of their neighbouring words and associations are similar. These are indirect, higher-order associations, and provide the context in which the search engine can index keywords. This context plays a crucial role in search; first, in the interpretation of the user query, and second, it is reflected in the results returned to the user.
Search-engine algorithms assume that the user is context-driven, and attempt to model the user's intent using higher-order contextual information gathered from available web pages. This process also models the brain's ability to extract context and semantic associations from information.

People with Autism are less context-sensitive and prefer a more detail-focused processing style [30], and form search queries very differently. Individuals with Autism are also less likely to engage in a relational (hierarchically organized) style of processing [27] suggesting that relating information in a hierarchically organised framework is less likely. Hierarchical organisation implies a great deal of flexibility and mental-shifting, as a simple example, in a search for 'apple', it would imply awareness that the word is related to 'pear' but also to 'fruit'. Awareness of this latter relation also suggests awareness that 'apple' is related to 'pomegranate'. This is of course, a simple example, but these associations can get very complex very quickly. Generally speaking, individuals with Autism prefer, and are more likely to engage in an item-specific processing style, and, whilst intelligent cognition is definitely possible, search queries are more likely formed of first-order associations[1].

2.4 What should Search offer people with Autism?

2.4.1 Search and Learning

The Internet is one of the largest resources of information. Search engines allow users to collate hundreds of links on a single topic, using only a few words or phrases. The user sorts the returned results into 'relevant' or 'irrelevant' categories, flexibly shifting (mentally) between one result and the next, to determine the relevance of each page returned by the search engine[2]. Search allows the user to assimilate the information on the page into their knowledge and is an important learning tool; its significance is duly noted because of the learning benefits it brings for children and adolescents as they begin to navigate the Internet and gain an understanding of several subjects.

2.4.2 Clues from virtual reality and gaming

Almost all teenagers (97% of those aged 12-17) use a computer, web, portable or console device, 73% of which is desktop/laptop based. Teenagers with Autism also use technology and spend a substantial amount of their time using devices [10]. For individuals with Autism, computer-based technologies can provide a stable, consistent learning environment that can be customized [4].

2.4.3 Motion Controllers

Motion recognition devices can be programmed to make consistent responses to environmental triggers. This is unlike real-world situations where environmental responses are not always consistent and may require further interpretation or guess-work. These controlled and interactive environments have shown promise for improving social communication skills and reducing repetitive behaviours [1].

[1] Of course there is a great deal of individual variability in the Autism Spectrum.
[2] In the typical case

2.4.4 Visual not text-based

People with Autism demonstrate stronger visual memory [15] than verbal memory, so a more visually-oriented approach to search (reducing the 'working memory' load [5]) is a more appropriate way to present data to bolster the strength of visual memory in people with Autism.

2.5 Existing Combination/Advanced Search Engines

The first part of this project involves the synthesis of results from three leading search engines. Current existing solutions are:

2.5.1 Bing vs Google

'Bing vs. Google' presents the users search query results from both search engines, allowing the user to make a comparison, and provides the experience of navigating both search pages simultaneously. The number of other personal preferences options is very limited, and there is double the information on the page (verbal overload).

2.5.2 Qrobe.it

Qrobe combines three search engines results (Google, Bing and Ask) and presents them conveniently on one page. Unlike Bing vs Google the user can search web, images or popular. Qrobe has not got an open (or well tested) API for developers to use to extend its functionality further, meaning it is a riskier option to choose for this project.

2.5.3 AskBoth

AskBoth is a work in progress, and combines both Google and Bing, with a section in the middle dedicated to twitter. AskBoth argues that the selling points for the site are its uncomplicatedness, aesthetics and user experience (UX) which promises to be particularly good (promised, since 2009!).

2.5.4 Spectra

Spectra (results from Google, Bing and Yahoo), allows users to assign weights and determine the way results are displayed. Spectra gathers the search results, ranks them and displays them according to their algorithm. Spectra does not provide an API for developers, and the rigor of the search is hard to test, (not much user data available to analyse).

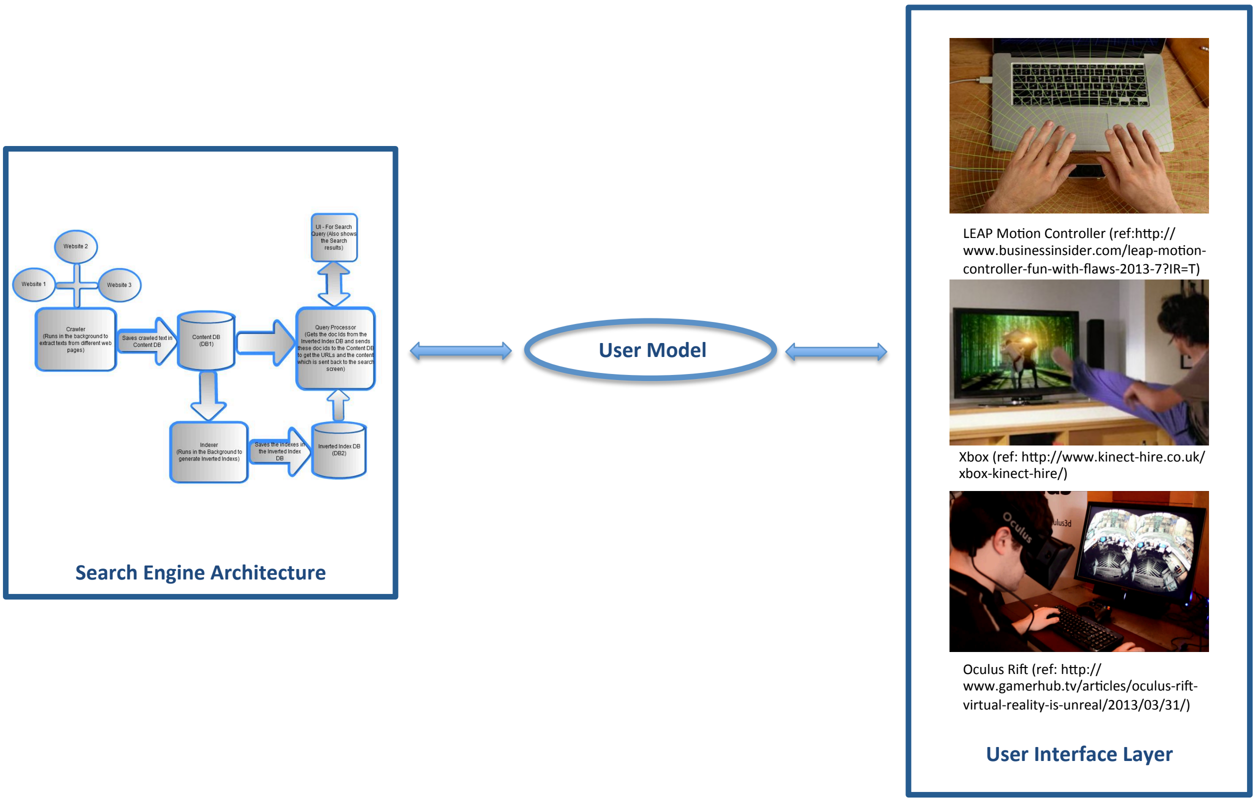
2.5.5 Conclusions and ways forward

These search engines allow users to see more results than what one search engine alone would present. Bing vs Google, and AskBoth, do this at a cost – redundancy (near-duplicates) and cognitive overload. This is not ideal for users with Autism, as this is precisely the opposite of what the application's aims and objectives were (see Section 2.1). Spectra and Qrobe, do not offer an Open API and are not suitable solutions for the current project.
I will work on the creation and synthesis of the results using the Google, Bing and Yahoo API's, and incorporate a user model of Autism.

3 Aims and Objectives

I propose to build a user model within Search for people with Autism. The user model will refine search results based on the presence of first-order, or, item-specific relations to a search query (rather than hierarchical relations). The search results will be assessed for the Key Word In Context; use a similar order of semantic association to the search query; and, present the user with smaller snippets. The model will be developed around well-understood cognitive processes in Autism. Other elements of the user model will be decided with user-feedback (during testing).

3.1 Proposed Search and Controller Web Application



Proposed application: The User Model will be applied to existing Search Engine Architecture[17], and be integrated with a Motion Controlled interface.

3.1.1 Core Features

1. A web application that synthesises the results from three of the largest and most popular search engines (Google, 67.5%, Microsoft Bing 18.4% and Yahoo 10.3%) [26]

2. The design and implementation of a stereotyped user model of Autism to filter user search results

3. Key Word In Context search; returning verbally-concrete, not text-overloaded results, in a consistent manner.

4. Prioritisation of results which have first-order semantic relations to the query words (see Section 2.3), i.e., they appear in matched context to the search query.

5. Motion controlled UI (see Section 4.3).

3.1.2 Non-core Features

1. Implement a higher ranking for pages with most images.

2. Use of WebGL and the three.Js library for 3D UI .

3. Compatibility with other motion controller devices (e.g., head-mounted devices).

4 Plan for Developing the Solution

4.1 Creating a User Model of Autism

4.1.1 What is a user model?

User modeling has strong implications for human-computer interaction (HCI); by creating a representation of the user, the system can be better informed about how to behave in various circumstances, e.g., the users demographics, needs, preferences, likes, dislikes, goals, plans, knowledge, and skill. A user model is a collection of information associated with a particular user (usually a data structure), with which a system can adapt/customise its behaviour in line with the users needs. The information can be gathered when the user 'sign's up' for the service (e.g., Google+, Facebook), and starts the formation of a data model.

4.1.2 Types of user models

User models can be static, and unchanging (i.e., no algorithms are used in order to teach the model about the changing preferences of the user, and no new information is fed into the model), or dynamic (representation of the user with their up-to-date changes in interests, and recent interactions with the system). User models may also be stereotyped. This is when the system infers or assumes characteristics about a user from data gathered from other users within that distinct subset. Lastly a user model can be highly adaptive and try to model the one user on their own, without stereotyping or inferring the characteristics of the user, however this requires a large amount of data collection before implementation.
A stereotyped user model will be used. Basic information will be gathered via a registration process, and added to a user model of ASD. The benefits are that the model can be built quickly using clusters of characteristics of individuals with Autism.

4.1.3 Adaptive / Personalised Search

Adaptive or Personalised search associated each user with a HTTP-cookie containing information such as login information (gender, age), preferences (languages, interests) and other information about previous searches based on site traffic. This allows the website to remember what buttons the user clicked on, or what sites they visited. This cookie record allows the search engine to return results that are highly relevant to the search query, but also highly relevant to the pages that the user visited through previous searches.

4.1.4 Disadvantages of Current Adaptive Search for Individuals with Autism

Although adaptive search seems to have significant user benefit in terms of relevance to the user for that search query, it decreases the likelihood that the user encounters new information and biases the results towards the users location and their previous site traffic. This has the unwanted effect of creating a filter bubble (Pariser, 2011), which is argued to close us off from important and relevant information and create a personal ecosystem of information for one particular user, creating the impression that our narrow self interest is all that exists. The filter bubble also has potential privacy problems, as the user may be unaware that the search has been specifically tailored towards their interests and they wonder why things that they have previously searched for have become more and more relevant. There are search engines that have attempted to address this unwanted effect, by not tracking or saving user information (e.g., DuckDuckGo.com). As users are not linked to their search queries, it limits them being targeted by adverts related to their previous searches. Unfortunately the filter bubble may positively reinforce restricted interests in Autism as the user constantly receives feedback about their previous (idiosyncratic and personalized) searches without being able to break out of that repetitive loop.

Recent research has suggested personalization also increases background noise relative to the search results [7]. Briggs (2014) suggests that there is a carry-over effect in personalized search for the users, whereby prior search results influence the results of subsequent searches. It should be noted that personalization of search results generally takes a lower priority for the ranking algorithms than the URLs ranked top in terms of their relevance for the search query. Nevertheless this carry-over may be particularly disadvantageous for people with Autism (some of whom already have restricted and repetitive interests) as it muddies their search space.

In order to produce a search tool specifically tailored to reduce the filter bubble effect in Autism, widen the information gateway and reduce the possibility for restricted and repetitive searches, the weighting on previous search results needs to be reduced. This is something I will investigate in the project, particularly for individuals with restricted interests. For these users, it would limit the possibility that they get trapped in a spiraling loop of ever-narrowing user-relevant information and over personalization of self-reinforced information ecosystems.

4.1.5 Persisting the User's Information

The user will be asked to authenticate a link between their Google+ account and the web application. The Google+ API includes methods to access 4 resource types; People, their Activities, Comments and Moments. A person is represented with many fields in Google +, including name, gender, title, occupation and so forth. Information about web-search history for any individual user can be obtained from the browser history.

4.2 Implementing the Application

4.2.1 Selecting Search Engines

The three most popular search engines (as calculated using an average of the unique monthly visitors) are Google (1,100,000,000), Bing (350.000.000) and Yahoo! (300,000,000)[23]. Google is the goliath question-answering system (query volume = 64.5%)[26], and is often considered the most innovative and dynamic. It is popular amongst users worldwide (using global traffic rank figures, in March 2015). Yahoo (2003) was the first ever web directory service; it has stronger advertising and e-commerce partnerships and has a query volume of 19.8%. Bing was officially launched in 2005, and has a query volume of 12.8%, which is substantially less than Google, but nevertheless, is within the top 3 search engines. Other search engines were not included, to limit redundancy of the search results returned (see Section 2.5).

4.2.2 APIs, Text-Search Libraries

I will use APIs provided by Google, Yahoo and Bing. These are more efficient than inspecting the source code for each search-result page (e.g., the Apache Lucene Key Word In Context (KWIC) library is optimised for maximum search efficiency see Section 4.2.7).

4.2.3 Google Custom Search

Google Custom Search (GCS) API (available in Java) can be used to create a personalised search engine. GCS requires a domain name and server at configuration, and provides a consumer key and secret, which are hardcoded in the application.
Using the API I can extract image search results, page dates, formatting dates, custom snippets, and sort and filter the results. The API alone may not be comprehensive for textual-search (KWIC), and an addional library may be required (see Section 4.2.7). Costs $0.01/search.

4.2.4 Yahoo BOSS

To use the Yahoo BOSS Java API, I will create a search engine 'project' to obtain a consumer key and secret. The API offers similar functionality as the GSC, so is not sufficient alone to reach the goals of the project. Costs $0.01/search.

4.2.5 Bing Search API (Data)

The Bing Search API can produce results for Web, Images, News, Videos, Related Search. It also includes spelling suggestions based on the query entered. Costs $0.00/search (max 5000 searches/month)

4.2.6 Faroo API

Faroo is a free (Java) API, claiming to combine Google, Yahoo and Bing. Faroo can return news search, trending pages, and can sort results [29]. However, as it only offers Web Search from 2 billion pages it has indexed (compared to Google: 46.7 billion [20]), it is not comprehensive enough for the current project.

4.2.7 Apache Lucene Library

Apache Lucene Library is a text-search library (written in Java), and provides powerful, scalable, accurate and efficient algorithms to search textual data. The API offers the possibility to carry out phrase, wildcard, proximity and range queries. The library also affords ranked searches, with type tolerant suggesters and field searching.

4.2.8 Key Word In Context

The Apache library also allows contextual-text search, also known as Key Word In Context (KWIC)[16]. KWIC works by forming an index to allow each word to be searchable. The library takes care of the efficiency of this process, and can return weighted terms of a given query (as an example).

4.2.9 Google+ API

A user will first authenticate their personal Google+ user profile with the web application being developed, and these data (including age, gender, lifestyle, frequent tasks, tools/resources commonly used) will therefore be acccessible via the API (available in Java)[3].

[3] It is also be possible to store information in the 'about me' section on the profile about individual diagnosis (Autism, Asperger, and high/low functioning). This information can be parsed when the query is submitted to the search engine.

4.2.10 API for 'LEAP' Motion Controller

LEAP Motion SDK offers an API to get tracking data from the LEAP Motion Service. A WebSocket interface, allows LEAP Web Based applications, and a WebSocket server listening in on http://127.0.0.1:6437[4]. The server sends tracking data in JSON messages and an application can send configuration messages back. This library will be used to establish connection to the server and consume the JSON messages [6].

4.2.11 ThreeJs Library (Non-Core)

This Javascript library enables WebGL-3D in a web browser. WebGL brings hardware-accelerated 3D graphics to the browser without installing additional software. This library may be used to better integrate the application with the motion controller, and improve the experience of embodiment, UX, and UI of the application.

4.3 Integrating the Application with Motion Controller Hardware

4.3.1 Hardware Selection Process

Two options were available; the Oculus Rift Virtual Reality head mounted display, and, the LEAP motion controller. The hardware was selected as follows:

1. Accurate timing of the device correlates a good UX. The LEAP has options to poll frames at a constant rate (to keep timing of movement accurate).

2. Cognitive lag time. Each of our senses operates with a different lag time. Hearing has the fastest sense-to-cognition/understanding time; sight is the slowest. The device should therefore work with the combinatorial configuration of the senses.

3. As this is a tool to be used with individuals with Autism, the sensory experience (imposition) of the device cannot be overwhelming.

4. Cognitive-load should not be high (operating the device should not require a great deal of cognitive effort).

5. The device should integrate with concrete behaviours, e.g., drop or grab.

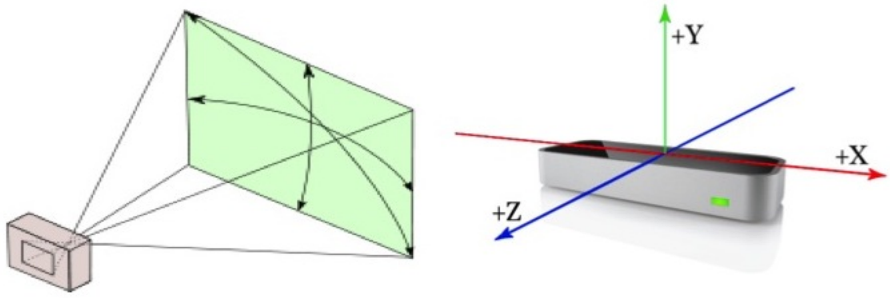
6. Affordability for users.

The two main reasons to persue the LEAP before the Oculus VR were, (1) it's non-imposing nature (no head mount), and (2), the affordability of the controller.

4.3.2 LEAP Controller

The LEAP can recognize and track hands, fingers, finger-like tools, positions, motions and gestures using infrared light and optical sensors along the x, y and z axes (cartesian coordinate system). The controller has a 150-degree field of view, and can operate in a range of 1 inch to 2 feet. The API works with distance in millimetre resolution. Time is measured in microseconds, speed in mm/s and angles in radians.

[4]The user can enable or disable the WebSocket server as they choose to do so, in the device's control panel.

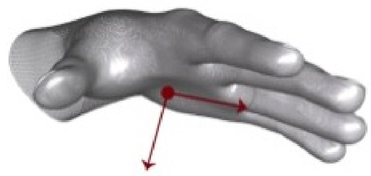


The LEAP controller, with 150 degree view [6].

The LEAP uses frames to represent tracked entities such as hands, fingers, tools or gestures. Motion data is recorded as a set of frames (stored, read-only) containing the detected information. Frames can be created by calling the Controller.frame(). Up to 60 can be held in the history buffer. Frames may be 'dropped' if there are resource contrainsts, or, they are missed.

4.3.3 Hands

The Hand class, returns information about the position of fingers, and arm (left/right).



The Hand palmNormal() method and direction vectors define the orientation of the hand [6]
.

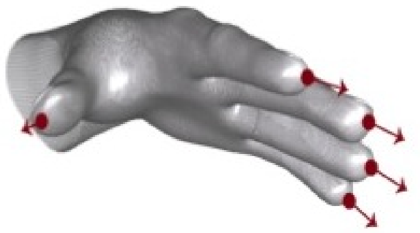
The software uses parts of visible hands, internal models and previous observations to form a model of the hand. There is a Hand.confidence() method that provides a rating of how well the observed data fit the internal model [6].

4.3.4 Arms

The Arms class can return information about orientation, length, width and end points of movements. The LEAP controller software bases these return measurements on previous observations of the user, and using typical human proportions.

4.3.5 Fingers

These characteristics are based on the anatomy of the hand, and recent observations.



Finger tip position and direction are given as vectors. [6].

4.3.6 Tools & Pointables

Tools can represent any real object (noun), but are longer, straighter and thinner than fingers. Tools must be cylindrical.

4.3.7 Gestures

The LEAP recognises certain movement patterns (CircleGesture, KeyTapGesture, ScreenTapGesture and SwipeGestures) allowing the user to indicate an intent.

4.4 Project Plan

4.4.1 Project Timeline

The start date of the project is June 5th 2015, and end date is September 13th 2015.

Table 1: Project Stages

Dates	Task	Priority
Jun 05 - Jun 12	Configure relevant API's & Libraries to domain name/server	MUST
Jun 13 - Jun 19	Synthesise search results	MUST
Jun 20 - Jun 27	Research & build user (and data) model of Autism	MUST
Jun 28 - Jul 06	Work on configuration with Google+ API	MUST
Jul 07 - Jul 14	Apply user model to Search	MUST
Jul 14 - Jul 21	Develop UI	MUST
Jul 21 - Jul 28	Integrate motion controller tools	MUST
Jul 29 - Aug 05	Develop questionnaire and eye-tracker set up	MUST
Aug 06 - Aug 13	Test the model and ask for user feedback	MUST
Aug 14 - Aug 21	Revise the user model and UI	MUST
Aug 14 - Aug 21	Develop UI with other motion controllers	COULD
Aug 22 - Aug 29	Develop UI using WebGL/threeJs library	COULD
Aug 22 - Aug 29	Write up project report	MUST
Early Sep (tbc)	Present findings to supervisor	MUST
Sep 13	Submit report	MUST

4.4.2 Methodology

There is a relatively short deadline in which a single developer will research and deliver a system prototype and report. The APIs, technology and areas of development are unfamiliar. As the final product depends on user feedback testing, there is an element of uncertainty about what the final product will be/should look like. These characteristics suggest that the most suitable methodology to deliver the application is an Agile-like Methodology. I will focus on early development and rapid feedback to make adjustments to the project's direction. This methodology offers the most flexibility and adaptability.

4.4.3 Development Languages

The Google, Yahoo, Bing and Apache Lucene APIs are available in Java. The LEAP SDK sends Frame information in JSON format to Web Browsers. As a non-core feature, I may use a 3D interface with the three.Js library which is also JSON format. I will use HTML5 for the development of the aesthetics of the Web Application itself. For testing I will use JUnit, JSON Test and Mockito (for user/external dependencies).
JSON is light weight, language-independent data format, and a good tool for sharing data. Importantly JSON offers faster execution and server-side parsing by storing the data in arrays, so that the transfer of data is faster. Faster parsing is particularly important for sharing the LEAP motion controller data. Some of the drawbacks of JSON are that it only has limited support tools available, and little error handling capabilities. It is also vulnerable as it returns responses in wrapped function calls which are vulnerable to attack. Java is a platform and operating-system independent language. It offers a simple, dynamic, robust object oriented, and functional language. There is excellent documentation available for the language, with many third party, open source libraries.
I will use Eclipse text editor and attempt to make the application compatible with Google Chrome browser (as it is WebGL-compatible and useful for 3D interfaces). I will use Git for Version Control.

4.4.4 Testing

4.4.5 User Testing

I will test the application with a group of individuals with Autism. I will

1. Invite adolescents and adults Autism to use the web application.
2. Obtain their feedback (relevance/explicit feedback, and, implicit feedback, e.g., 'clicks').
3. Design a questionnaire to gather qualitative data.
4. If time allows, I will use the Tobii Eye-tracker TX300 (Department of Psychology, Birkbeck University of London) to gather high resolution eye-tracking data as users test the application.
5. Revise the model and ideas. Choosing the best possible approach/tools to achieve optimization for this group of individuals.

4.4.6 Unit Testing

I will be implementing Test Driven Development (TDD)[5] with JUnit (version 4.12), and where there are external dependencies, these will be mock tested using Mockito [6]. JSON Test will be used to test JavaScript Object Notation [11]. I will run both unit and regression tests.

[5] The TDD process involves iterating through the write-test-then-write-code process. First writing a test for some functionality, and second, writing just enough production code to make the test pass.

[6] mockito.org

4.4.7 Risks/issues, probabilities and mitigation of impact

The risks associated with the project, their impact and how I will mitigate them, is outlined in Table 2.

Table 2: Risks & Impact Mitigation

Liklihood	Impact	Risk	Mitigation
LOW	HIGH	API's require significantly high payment	Find/use alternative
LOW	HIGH	KWIC library does not offer methods needed to achieve goals of contextual text search	See if I can implement the method, or find additional API
LOW	MEDIUM	Cannot get research participants with Autism to take part in a usability test	Expand age range of interest in attempt to find participants
MEDIUM	MEDIUM	Google+ API does not configure a user persona/user model well	Use Facebook or alternative
MEDIUM	HIGH	LEAP does not integrate with web application	Investigate user forums, contact LEAP to source answers, adjust web application accordingly.
MEDIUM	HIGH	User Model lacks power and users are unhappy with the Search system	Gather feedback for a further iteration. Modify weights of parameters in the algorithm. Revise the model.
MEDIUM	HIGH	Not enough turn around time to implement the feedback	Develop plan and prototype in time for report submission

4.5 Summary & Concluding Statement

I have proposed to research and build a User Model within Search for people with Autism. I describe a model (based on well-understood aspects of cognition in Autism) to apply to search results, using text and content based libraries which will refine search results for these individuals. I hope these insights will assist with the forthcoming information-overload problem by exploiting these user models to turn the masses of information available into a specific set of information goods.

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