Plan Outcome

An issue which I will seek to resolve is how some people suffer from back pain, from a range of causes including heavy lifting, bad posture or old age. The target audience will therefore include older people, and students who carry around heavy backpacks for schooling. An outcome I will seek to create to fix this is a wearable electronic back scratcher.

The implications of this outcome include:

* Intellectual Property – The outcome should consist of systems which I have the right to use, whether they be free to use or have fees I have paid for
* Usability – The control interface for the backscratcher should be intuitive and easy to use
* Functionality – The backscratcher should have full back reach
* Health and Safety – The back scratcher shouldn’t inflict any injuries onto the user, such as colliding into the back with high power
* Accessibility – Wearing the apparatus shouldn’t be complicated
* Aesthetics – the apparatus shouldn’t be off-putting in its appearance
* Sustainability and future-proofing – The apparatus should be made of material which is as unharmful to the environment as possible. The code should also be easily updatable and the apparatus itself should be easy to repair in the event of damage

Requirements:

* The resources will consist mostly of systems which I already own and therefore have the right to, and any other resources I will obtain legally
* The app which I am planning to control the apparatus with must be self-explanatory
* The apparatus must be capable of moving in 3 dimensions for full back reach and pressure
* The apparatus must not be capable of forceful movements
* The apparatus must involve as few straps or other means of mounting as possible
* The electronics of the scratcher should be as hidden as possible
* The main material of the apparatus must be easily recyclable or biodegradable
* The apparatus should feature a clear port to access the microcontroller for updating code
* The distinct moving parts of the apparatus shouldn’t be permanently connected, for easy maintenance

Communication Protocols, Components and Subsystems:

* The outcome will be a robotic arm mounted at the back of the neck, which will extend to reach throughout the back. I find this to be the best method of satisfying the outcome as it will make the apparatus easy to wear, being attached at only one point.
* The apparatus will be controlled by a smartphone app, which will have buttons for moving the arm in three dimensions. I find this to be most suitable as it gives the user precise control over where exactly they want the arm to be and how much pressure to apply.
* The head of the arm will have a blunt point, with the ability to perform small movements to satisfy an itch. I chose this as the best design for the head as it is not sharp, reducing risk of harm, while also having a full ability to satisfy the user.
* Bluetooth will be used as the communication protocol between the smartphone and the apparatus. This is because it can send information quickly at short distances with no existing network.
* The arm itself will move by use of multiple servo motors, enough to precisely reach all regions of the back, and the head will have its small gyrating movements controlled by a motor
* The processing and control of the motors will be done by an Arduino Uno microcontroller with a Bluetooth module for wireless communication. This is because it is a small microcontroller with all the connection potential I need, without being unnecessarily advanced.
* The apparatus will be powered by the USB output of a power bank. This is because it is rechargeable, and therefore less wasteful than batteries, and will also be inexpensive during testing as I already own one.
* The main structural material will be 3D printed PLA plastic. This is because it is corn-starch based and therefore has a minimised effect on the environment while still being structurally secure, and is 3D printable, so I can make specific designs to suit my production needs.

Purchasing Components

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Component | Quantity | Specifications | Source | Description |
| Servo Motor | 4 | High torque | [AliExpress](https://www.aliexpress.com/item/32854187745.html?spm=2114.search0104.3.2.5b8c7be6pAJqcU&ws_ab_test=searchweb0_0%2Csearchweb201602_4_10065_10068_10547_319_10059_10884_317_10548_10887_10696_321_322_10084_453_10083_454_10103_10618_10307_537_536%2Csearchweb201603_52%2CppcSwitch_0&algo_expid=a591820d-2441-43ee-a355-40a0531c66a6-0&algo_pvid=a591820d-2441-43ee-a355-40a0531c66a6) | Will be ordered early in the project to allow for delivery time. |
| Motor | 1 | Average torque | [Jaycar](https://www.jaycar.co.nz/search?text=motor&CSRFToken=b775d0da-ed44-49d9-8e12-49545f7dcd35) | Will be bought locally, despite the higher price, as it is needed earlier in the project and the price is still not very high relative to buying the servos locally |
| Bluetooth module | 1 | Ideally an HC-05 module as I have found a tutorial for this | [AliExpress](https://www.aliexpress.com/item/32612978653.html?spm=2114.search0302.3.2.42d854f2I8m6qD&ws_ab_test=searchweb0_0%2Csearchweb201602_0_10084_10083_10547_10887_10307_321_453_10548_322_454_10618_536_10065_317_537_10068_319_10059_10103_10884_10696%2Csearchweb201603_0%2CppcSwitch_0&algo_pvid=4421341d-e40d-40cc-9508-1ba77394714a&algo_expid=4421341d-e40d-40cc-9508-1ba77394714a-0) | Will be ordered with the servos, once again to allow for the lengthy delivery time |
| Power Supply | 1 | Will need a certain voltage and current rating | Already owned | Once I have finalised a design, I can select from power supplies I already own (battery packs, power banks etc) which meets the design’s requirements |

Sprint 1 Review

**Did I finish all the tasks I planned for? If not, why?**

Yes, the externally sources components are ordered and I have learnt various modelling techniques in fusion 360, enough to model my necessary parts.

**Regardless of what tasks you completed, does your “shippable” /** **“testable” product look like what you planned?**

While no physical product is constructed yet, I am in the situation I planned for in this sprint.

**Are you happy with the standard of the “shippable” / “testable” product you produced? Why / Why not?**

Yes, once again while no product exists yet I have completed my tasks to a high standard

**Did you do any extra tasks that you did not plan for?**

No

**How did the information gathered from the planning, testing and trialling (including user feedback) of components enable you to develop a high-quality “shippable product”**

* **This should include evidence of how the outcome addresses relevant implications**
* **How has this sprint improved the overall quality of your outcome?**
* **How will this information inform the next sprint**

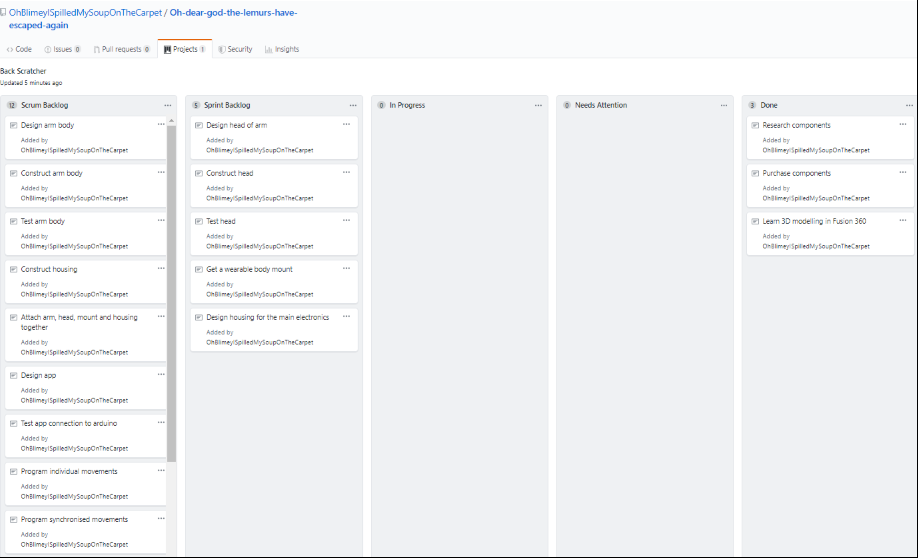
Again, no product exists yet (as planned), however the information of 3D modelling which I have gained will contribute towards the aesthetical implications of the product, as the skills I have gained will allow me to create detailed and therefore aesthetically pleasing designs. This 3D modelling will greatly inform the next sprint as it largely involves 3D design, and the quality to which I researched 3D modelling will improve the quality of these designs.

**What communication protocols were used during this sprint? Why? How?**

None

**What is the function and behaviour of any new components that were used during this sprint?**

None

**Planner as of the end of this sprint:**

Sprint 2 Review

**Did I finish all the tasks I planned for? If not, why?**

I did not finish all tasks planned for, however I substituted the tasks I did not finish with an equivalent task from the next sprint, constructing the electronics’ housing instead of the scratcher head

**Regardless of what tasks you completed, does your “shippable” /** **“testable” product look like what you planned?**

The design of the scratcher head is different than what I planned. I planned a single gyrating point but instead used a spinning plate of 4 points (see testing/evidence document). This may see the back scratcher be more of a “back massager” which” however this will still carry out the goal of soothing the hard-to-reach areas of the back. But besides this the head, with its current design, is precisely as planned.

The housing of the electronics is smaller than I imagined, now featuring a case around the Arduino which I plan to attach with Velcro to the strap of a modified backpack to mount the arm onto.

**Are you happy with the standard of the “shippable” / “testable” product you produced? Why / Why not?**

Yes, while I did make revisions, I believe these were in the best interest for the efficiency of both the manufacturing process and its ability as a back scratcher.

**Did you do any extra tasks that you did not plan for?**

Yes, the construction of the housing for the main electronics (Arduino board).

**How did the information gathered from the planning, testing and trialling (including user feedback) of components enable you to develop a high-quality “shippable product”**

* **This should include evidence of how the outcome addresses relevant implications**
* **How has this sprint improved the overall quality of your outcome?**
* **How will this information inform the next sprint**

The information I gathered throughout this sprint includes a rough vision of how the apparatus will come together, and further experience designing and constructing components. Altogether this sprint has addressed implications including:

* Accessibility – the housing makes accessing the ports and electronics simple
* Future proofing – the housing’s port access makes updating the product’s program simple
* Aesthetics – planning the colour scheme to 3D print the parts in will make the product aesthetically pleasing

This sprint has contributed towards ensuring the basic physical features of the apparatus are effective in their purpose. Moving forward I will use the rough vision of the end product which came together while designing parts in this sprint.

**What communication protocols were used during this sprint? Why? How?**

None

**What is the function and behaviour of any new components that were used during this sprint?**

* The housing – this has a very simple purpose of protecting the main microcontroller, while allowing a body for it to be mounted with, while the microcontroller inside shall serve the purpose of running the program which will control the apparatus based on app inputs
* The head – While not constructed yet, this will serve the purpose of carrying out the scratching/massaging motion at the end of the arm
* The mount – Will be a chassis for the whole apparatus

Sprint 3 Review

**Did I finish all the tasks I planned for? If not, why?**

Not exactly, the sprint took roughly a week longer than expected, however rather than running the uncompleted tasks into the next sprint I have considered this to be taking off the spare week I allocated at the end of the project before it is due, as this is the primary reason why the spare week was allocated.

I did not achieve all these tasks because they took more time than I allocated for them and I ran into more set-backs than expected

**Regardless of what tasks you completed, does your “shippable” /** **“testable” product look like what you planned?**

Yes (by the end of the extra week which I am considering to be an extension of the sprint), all physical connections and wiring of the apparatus are complete, all tasks left are software-based as intended.

**Are you happy with the standard of the “shippable” / “testable” product you produced? Why / Why not?**

Yes, I am taking much advice from potential users (my parents) and iteratively making improvements as I come across them rather than leaving it for later. Examples include the addition of rubber bands to reduce the motors’ load, and re-designing and re-printing arm stalks to account for this.

As a result I am confident that the project will need very few, if any, final adjustments, which will save time by making the “make any necessary adjustments” task of the next sprint much shorter

**Did you do any extra tasks that you did not plan for?**

Briefly, yes. In testing the circuits of the constructed arm I had to create scrap scripts which programmed for individual motor movements, therefore starting the “program individual movements” section of the next sprint. However, I would not consider this task done as I intended for it to be individual movements as controlled by the app, and the app is not programmed yet, although doing part of this task now will make this task much easier next sprint.

**How did the information gathered from the planning, testing and trialling (including user feedback) of components enable you to develop a high-quality “shippable product”**

* **This should include evidence of how the outcome addresses relevant implications**
* **How has this sprint improved the overall quality of your outcome?**
* **How will this information inform the next sprint**

This sprint had concluded the construction of the physical components of the apparatus and has therefore addressed all the physical-related implications and others, including:

* Intellectual property – all software used to model the parts was one which I have free legal use of, and the models I used, while inspired by other examples, were all of my own making.
* Functionality – The head of the scratcher has a wide 3-dimensional range of reach due to the nature of the construction, allowing for full back reach.
* Accessibility – The backpack containing the apparatus is relatively simple and familiar to wear as an average user, being the same as a regular backpack (2 straps) while also requiring awareness and avoidance for the loose wires
* Aesthetics – The consistency of a colour scheme and management of wires makes the apparatus pleasing to view, this could be improved on in terms of cable management but considering the time constraints, other aspects will be prioritised such as functionality, so the aesthetics, while adequate, are unlikely to be improved upon.
* Sustainability and future-proofing – The majority of the apparatus is made from PLA plastic, which is degradable and therefore has a minimal carbon footprint. Furthermore, the apparatus has exposed ports for software adjustments, and is separated into different components, making maintenance and repairs easier as only few parts must be removed in the event of damage

The effort applied in this sprint has contributed to the physical quality of the apparatus and this high quality will result in an overall better user experience through the implications described above. The information gathered in this sprint will

**What communication protocols were used during this sprint? Why? How?**

None, the Bluetooth module will soon be implemented in the next sprint

**What is the function and behaviour of any new components that were used during this sprint?**

The new components are those which make up the arm of the scratcher, including:

* The rotating base – this is connected near the back of the neck with cable ties and rotates to provide reach of the back besides a vertical line. This consists of a servo motor inside the base attached to a cap on top of the base
* The first arm stalk – This attaches to the rotating base, rotating by use of another servo motor and provides the first component of extension in the arm
* The second arm stalk – This attaches to the end of the first stalk and, using a servo motor, provides the second component of extension to position the head
* The wrist joint – Uses a servo motor at the end of the second stalk to angle the head into the back

Additionally, the electronics components are connected together with a breadboard mounted on the left strap and jumper cables, powered by a power bank on the right strap and controlled by the Arduino on the left strap below the breadboard.

Sprint 4 Review

**Did I finish all the tasks I planned for? If not, why?**

Yes, as the last sprint I finished all planned aspects of the apparatus to create a high-quality outcome. In this last sprint I mostly finalised the programming and linked it to the incoming data from the Bluetooth module, which was also coded for through the app created online with MIT app inventor.

**Regardless of what tasks you completed, does your “shippable” /** **“testable” product look like what you planned?**

Yes, it is capable of everything I had planned and more to a high standard, and there aren’t any obvious features left to be added, so the result is a fully functional back scratcher. As well as scratching, the apparatus has functionality similar to a back massager, and I am happy with this because in the experience of mine and others this has proven to be more soothing to the back.

**Are you happy with the standard of the “shippable” / “testable” product you produced? Why / Why not?**

Yes, the controls are responsive and the apparatus as a whole is relatively easy to use considering portability of such an outcome. User feedback has been acquired from a few candidates, including my parents and friends, and has been overall quite positive. A quality-related problem I encountered when testing the apparatus was some of the motors, mainly that of the wrist joint, ceasing function seemingly for no distinct reason. This took many iterations of testing to achieve a proper diagnosis, including making software adjustments, hardware adjustments (re-wiring) and testing the affect of other components on the faulty motors, all to see which factor was affecting it. This iteration eventually allowed me to conclude that my wiring was the problem, in which I bent some cables to manage them better for aesthetic purposes, unknowingly damaging the internal connections, and additionally the current was slightly too low to effectively supply some motors with power.

**Did you do any extra tasks that you did not plan for?**

The addition of a “reset position” button was not planned, however considering how simply of an addition it is and how much it adds to the usability of the apparatus, I would consider it a high priority feature.

Moreover, with an added time allocation before the deadline I added some unplanned features including vertical and horizontal scratch modes, which displace the head of the arm rather than just twisting the spike plate, as alone this twisting was not satisfactory enough. This could be considered part of the planned “make any necessary adjustments to apparatus” task, however these extra tasks are still unique as they were not directly planned for and wouldn’t have been accomplished without an extended deadline.

**How did the information gathered from the planning, testing and trialling (including user feedback) of components enable you to develop a high-quality “shippable product”**

* **This should include evidence of how the outcome addresses relevant implications**
* **How has this sprint improved the overall quality of your outcome?**
* **How will this information inform the next sprint**

Finalising the product, I wrapped up the addressing of implications and, in combination with those mentioned in previous sprints, I now believe my outcome addresses the planned implications. The newly addressed implications in this sprint include those below (see “evidence and testing” document for evidence.

* Usability – with the app finalised I can happily say that it is intuitive and self-explanatory to use, with buttons labelled accurately. As my target audience includes elderly people, who tend to have problems using newer technology, this is imperative
* Health and safety – with the movement speeds finalised, it can be observed that the movements in all directions are not fast enough to deal any damage to the user’s back through collision or otherwise.
* Intellectual property – with the project now finished, I can conclude that throughout the whole designing process I only used resources legally available to me and all creative property was my own
* Functionality – The addition of the unplanned scratching modes greatly adds to the ability of the apparatus to function as a back-soothing tool

This sprint has improved the quality of my outcome through all the software additions completed during it. This includes the range of navigation tools and togglable modes, with measures in place to avoid any damage to the user or the apparatus (custom set limits).

**What communication protocols were used during this sprint? Why? How?**

The communication protocol used in this sprint is Bluetooth communication. I chose Bluetooth as a communication protocol for my outcome primarily because it is a wireless communication method requiring no existing network and has responsive transfer times. The downsides of Bluetooth as a communication protocols are that it is relatively short-ranged and can’t handle large data transfers quickly, however these downsides do not apply to my product since the connected smartphone should only be in the hand of the user wearing the apparatus, so well within Bluetooth’s range. Furthermore, the only necessary data transfers are small amounts of output data from the app, further reinforcing the use of Bluetooth.

This wireless transfer operates by, according to the MIT app inventor code, sending different 2-3 letter sequences to the Arduino for each button activation, button deactivation or switch flip (I have programmed one sequence to be received per “click”, each click is 50 milliseconds long). The Arduino interprets these sequences and makes the corresponding changes to the apparatus and its position/state every click. However, before this can happen the back-scratcher’s Bluetooth module must be paired to the smartphone and then selected from the “select Bluetooth device” button on the app. All data transferences are entirely wireless, transferring over radio waves in accordance with Bluetooth’s protocol.

**What is the function and behaviour of any new components that were used during this sprint?**

This sprint’s new components include:

* Bluetooth module – allows connection and transfer of data to the Arduino from a smartphone, explained more above
* Power banks – the power supplies were finalised in this sprint, using one with two 5V 2A outputs to power the motors and a separate power bank with a 5V 2A output to power the Arduino. All these outputs are USB.

Other Necessary Statements

The CAD Process

As mentioned throughout this document, CAD was used to design and construct the custom parts of the apparatus. To clearly explain this process, I first 3D model the desired part from scratch (except for the Arduino case, for which I modified a design I found online) using a range of tools to manipulate a 3D object into my desired component. I then convert this to an STL file, which can be processed in slicing software to convert it to a gcode file which my 3D printer can be given, during this conversion I can set properties of the print including layer height and inclusion of support (scaffolding-like structures for printing aid). Once printed, I often made modifications to the components by repeating this process, starting with adjusting the 3D model, therefore using iterative development.

Testing Process reflection

I see my testing process to be beneficially vigorous and detailed, as a comprehensive range of expected, boundary and invalid tests were carried out, and any encountered issues were corrected as quickly as possible. This testing refined my outcome by ensuring all functional aspects of the apparatus are as error-free as possible, reducing any possible dissatisfaction by the user. For many of these tests I consulted with potential users from my target audience, including my parents (fitting the older section of the target audience) and my friends (fitting the student section of the target audience), so overall the result is a device with intuitive controls, which leaves little room for mistakes.