Imperial College London

SensUs

MINERVA

Imperial College London Team Results Document
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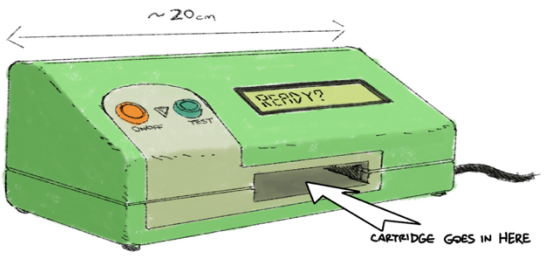

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1. Summary

Minerva is a team of ten undergraduate students, studying a variety of courses at Imperial College London. We are a motivated and ambitious team, with one common target shared; to design a biosensor for the detection of valproate in the blood and solve one of the main issues associated with the monitoring of epilepsy in patients. We have thrived on the unique experience SensUs have given us, to not only learn new skills and work with new people but also to follow an entire research and design process from start to finish!

Together, we have designed a microcantilever biosensor, utilising novel affimer technology to bind unbound valproate molecules (fVPA); allowing for label free detection. Our sensor features a unique microfluidic design, mixing modern pumping technology with a rarely seen droplet manipulation design. The use of SU-8 as the material of the microcantilever is rarely used commercially compared to the common use of silicon.

With the use of varied affimer technology and a replaceable cartridge our sensor also has the potential to be developed for detection of a variety of drugs and molecules, not only valproate!

Figure 1: Our team enjoying a weekly Zoom call!

2. Biosensor System and Assay

2.1 Molecular Recognition and Assay Reagents

A company called Avacta® have engineered protein scaffolds to be used in an alternative to antibodies, called affimers, which have none of the limitations commonly associated with classic antibodies [1]. Due to the constraints this summer of not having lab access, we have decided to outsource the affimers to ensure specificity to the valproate molecule is met. Avacta® make custom affimers using an online service and offer a strategic licensing agreement to customers who want to use the affimer technology in their products [2-3].

An affimer is a small molecule, usually a secondary protein, that has an amino acid sequence within the structure that can be changed without destabilising nor changing the entire protein structure. The scaffold protein in affimers is Adhiron [4]; and the variable region is shown by the two secondary structure loops shown in green in figure 2. After changing the small region of amino acid in this sequence, a series of proteins are produced that can be screened against a specific target to determine the best fit. This process is repeated 5 to 6 times [4] to optimise the affinity and specificity parameters. In this way, affimers are made to be more specific than antibodies whereby the non-specific binding to the sample would be minimal in our sensor providing more accurate results [4].

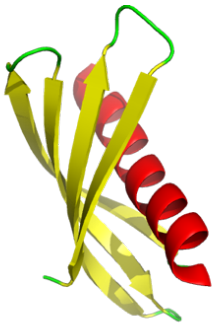


Figure 2: Adhiron protein scaffold imaged using PyMol.

The affimers will be immobilised on the microcantilever SU-8 surface, ready for specific binding to the valproate molecules. Since no acidic reagent is involved, dissociation of the bound VPA molecules is slower than the time taken for fVPA to diffuse to the affimer site, so only fVPA is measured. In order to 'wash away' the VPA for the next usage we will use a standard solution of ~ pH 2 which will dissociate the molecules, without affecting the affimer molecule which has a highly stable scaffold. There will also be a buffer solution used containing a known concentration of VPA to check the system is running correctly; and an inbuilt alert system if the expected reading is not given.

2.2 Physical Transduction

The concentration of Valproic Acid will be determined by a piezoresistive microcantilever biosensor, which experiences a stress, and therefore a resistance change, on one surface upon binding to the VPA molecules. A correlation between the concentration of analyte and the change in resistance will be established through laboratory research.

The lever piezoresistor will be connected to a Wheatstone bridge circuit for accurate resistance measurements. This signal will then be amplified and read by the microcontroller, calculating the concentration of the fVPA using the correlation factor found. The circuit diagram is shown in fig.3.

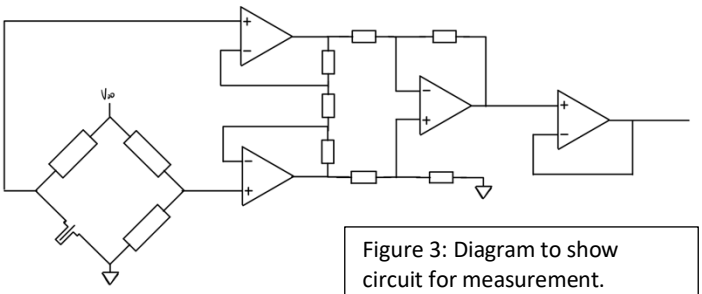


Figure 3: Diagram to show circuit for measurement.

The piezoresistive microcantilever base is made up 500um thick p-type silicon wafer which has a top and bottom layer of low-pressure chemical vapor deposition (LPCVD) low-stress nitride layer due to the need for KOH backside wet etching. This is to protect the piezoresistive layer and act as a blocking mask. Above the low-stress nitride layer, there is a 4um thick polymer SU-8 film [6]. The decision to pick SU-8 over the more commonly used silicon based microcantilever is due to the ease and low fabrication cost, making disposable strips more affordable, as well as the low elastic modulus which increases deflection. Following this, there is a polysilicon piezoresistive layer, with a thickness of 120 nm. To allow an electrical connection for wire bonding to detect the change in resistance, a layer consisting of 15 chromium and 150nm of gold is evaporated on the polysilicon layer. The chromium layer creates an interfacial layer to ensure the adhesive force is still present within the gold layer. To prevent electrical components interacting with the ionic solution, a 600 nm

thick plasma-enhanced chemical vapor deposition (PECVD) nitride film will top the previous layers. A final layer for the microcantilever itself is a deposition of gold and chromium nanoparticles at a thickness of 24nm and 6 nm respectively. The self-assembly monolayer (SAM), made up of the chemical 8-mercaptooctanoic acid, is injected into the microchannel of the microcantilever to covalently bond to the gold surface while the carboxylic acid at the other end binds to the 'Avacta' affimer technology.

2.3 Cartridge Technology

In our device ten sets of two detections take place. The first detection is of a sample with a known concentration of VPA, and the second is with the patient's blood sample, both carried out with a droplet of the fluid pumped from their respective inlet ports through the microfluidic circuit shown. The comparison to a known concentration increases the reliability of the reading and accounts for problems that would have affected the lever. Having ten readings increases the accuracy since they can be averaged, and anomalies ignored. A third droplet of solution after each set is also passed over the lever to wash it for the next set of readings, and also to calibrate to what should be a zero reading. Since droplets are being manipulated rather than a continuous flow (which also reduces considerations for flow effects on the lever) precise pumping control is needed. This is achieved using syringe pumps, and to keep the chip ergonomic these have been integrated onto the chip. They would be controlled by small linear actuators inside the device, connected automatically by the device upon cartridge insertion.

The chip would be made conventionally from PDMS with hydrophobic channels. The plugs would be fabricated using stereolithographic 3D printing and inserted into their channels once the chip is fully made. An air port in the chip allows the plugs to be inserted and acts to push the droplets along the main channel during use. The droplets would be guided by their entry-port channels to prevent them leaking out the air-port. The entry ports would be open to the air, allowing the three different fluids to be pumped along. Before use they'd be covered with a seal to prevent leakage.

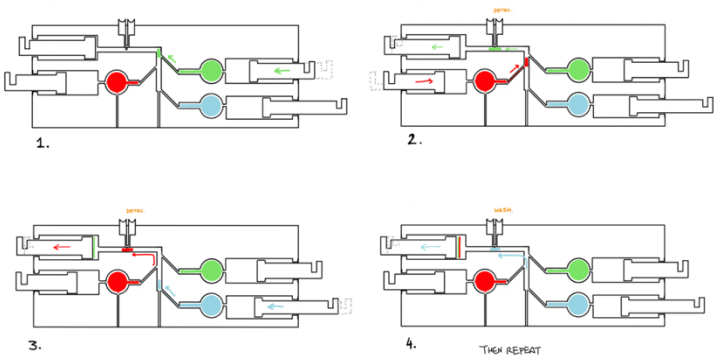
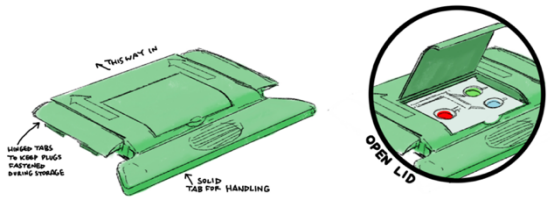


Figure 4: Microfluidic circuit schematic.

2.4 Reader Instrument and User Interaction

We have chosen to use React Native as the software in which to code our app for two reasons. Firstly, it meant that with the same code we can produce an app for both Android and iOS devices, reducing the time and cost needed to produce an app that will cover the entire market. Secondly, React primitives render to native platform UI, meaning our app uses the same native platform APIs other apps do and will map directly to the platform's native UI building blocks. We also created a website as alternative to the app, with information and contact details.



The user would deposit their blood sample in the cartridge and close the lid before inserting into the device, which would then be turned on. Prompted by the device, the user would then press a 'test' button and after a couple of minutes receive the results on a simple LCD screen, which the user would manually record in the app.

Figure 5 (left): How to use cartridge.

3. Technological Feasibility

3.1 Molecular

Figure 2 depicts an Adhiron [4] molecule, generated using PyMol. The molecule has been coloured based on secondary structure, the helix is shown in red, the loops in green and chain in yellow. Originally an Adhiron molecule has two chains; B and S depicted in fig. 6. One chain can be isolated, in this case B, and the amino acid code in the variable region changed using synthetic DNA to mutate the gene. Figure 6 shows the variable region of Adhiron and one of its affimers whereby the variable region has changed to an amino acid sequence (in one letter code) VVAG and PWEN.

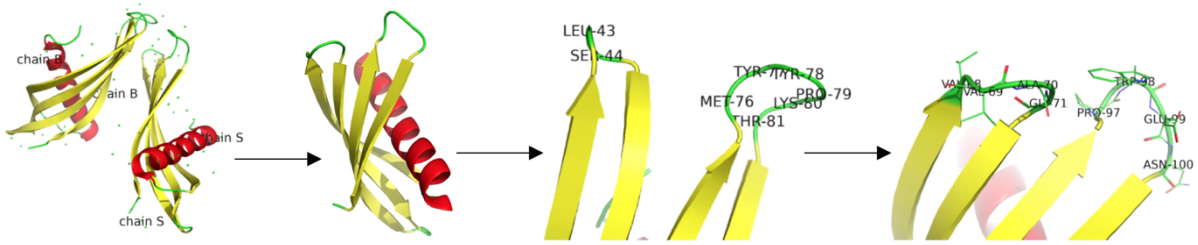


Figure 6: Process of affimer development using Adhiron .

Once a library of protein variants has been created, and screened towards valproate, an affimer will be chosen which exhibits 50% saturation of binding sites at the average concentration of valproate (the concentration at the midpoint of the dynamic range). This choice is to prevent a too high or low affinity affimer being chosen to minimise errors given in binding; errors will arise from the shifting of the curve resulting in a small error in measurement leading to a large error in concentration value. If bound too weakly the surface stress signal generated will not be strong enough; if too tightly the signal may become independent of concentration. If the dissociation constant were too small all binding sites would become saturated and the relationship between deflection and concentration lost. In this way the affimer we use will be tuned to give maximum sensitivity in our sensor.

3.2 Physical Transduction

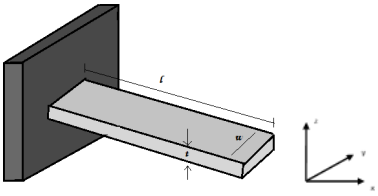
The use of microcantilevers has shown promise in various biochemical analyses. Despite microcantilever biosensors having potential in remote healthcare, the technique is not commonly used in commercialised technology. One huge benefit is that they are label free, and don't need complex optical equipment, allowing us to minimise the size, resulting in a low cost of fabrication [5] . They also have a fast response time and can be applied in a range of microenvironments, which make them a suitable option in drug detection in blood.
The relationship between resistance and surface stress will be calculated by repeated experimental procedures once the laboratories are open. This will be carried out by measuring the change in resistance against known recordings of surface stress. In order to derive this theoretically, we are relying on graphical results [5] from similar experiments; Using the Stoney's equation, we can establish a relationship between the deflection, surface stress, and concentration of analyte. The equation is given as [9] :

$$\sigma_s = \frac{Et^2}{6R}$$

Where, σ is the surface stress, E is the Young's Modulus, t is the thickness, and R is the radius of curvature of the microcantilever. The equation is generally used to quantify the surface stress in molecular thin films. Further generalising the equation shows the relationship between deflection and surface stress as follows [9] :

$$\Delta\sigma_s = \frac{Et^2}{3(1-\upsilon)l^2}\Delta z$$

Where, Δσ is the change in surface stress, Δz is the change in deflection, E is the Young's Modulus, t and l are the thickness and length of the beam, and υ is the Poisson's Ratio. As we are unable to derive a relationship experimentally, we will be relying on graphical results from experiments closely similar to our microcantilever.



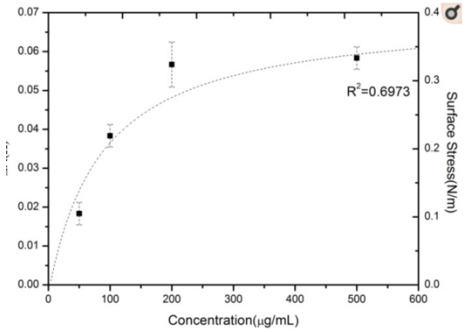


Figure 7 (left) : A simplified diagram of the microcantilever beam.
Figure 8 (right): Correlation between concentration of VPA, surface stress and change of resistance [5].

We decided to increase sensitivity of deflection of the microcantilever by using SU-8, which has a much lower elastic modulus of 4.4 GPa, 16 times smaller than silicon. SU-8 is less sensitive to temperature and pH, therefore average body temperature of 37°C and average blood pH [10] of 7.5 allow the biosensor to function without any complications. We model our beam as a simple rectangular shape to simplify calculations [8] . This is viable as analysis has shown that the shape or presence of any holes does not affect sensitivity substantially. Finally, to optimise sensitivity we must maximise length and minimise thickness. Therefore, the dimensions of the microcantilever are 1000 μm x 615 μm x 4μm.

3.3 Cartridge Technology

Ignoring the pumps, the circuit is based on an existing but rarely used droplet sorting circuit design [11] and almost certainly would work to pump the droplets as required, with fine tuning on the channel dimensions during experiments. In any case early development would focus on the chemistry of the detection, with a simpler circuit connected to external conventional syringe pumps. The full course of development may even show this to be more useful than any ergonomic benefits reached from integrating the pumps.

The actuators being used have a position uncertainty of 0.1mm. Accounting for the dimension difference between the pumps and the microcantilever channel and deciding that the droplet needs to be big enough that it'd be touching the lever despite this uncertainty, the droplets would have to have a volume of 1.2 microlitres, or a total sample volume of 12 microlitres, within the maximum volume. Experiments may show that the uncertainty is in face higher and therefore bigger drops and less drops might be necessary. It would also have to be investigated whether there is a minimum drop size for the concentration rather than the amount of VPA to be accurately measured.

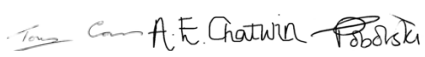
A reliable device would involve storing cartilages in bulk for time periods on the scale of months. It is unknown if the chip could be stored so long with no fluid leakage or material degradation and still give reliable test results. This would influence the use-by date of the chip and could necessitate storage of the no sample fluids separate to the chip. The integrated pump technology has recently been developed by a Parisian team[12] and they reported no leakage issues but this would have been on an immediate timescale rather than long term. Even without leakage there may be significant evaporation of the fluids. The question would be whether to add a surplus or to store the fluids separately. A wash droplet could precede the ten tests in order to clean the channels of any leakage or vapour.

Also required would be rigorous testing to see if the fluids inside the chip left their channels during handling. A simple solution would be a small Tesla valve between the entry ports and the main channel which could be overcome by the pump pressure. However, this opens a lot of questions that could only be answered in a lab.

4. Originality

4.1 Team document

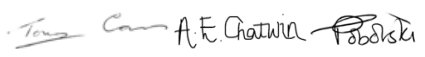
The originality in our biosensor lies in our choice of a microcantilever which is non-conventional and will leave us among pioneers of commercial application of the technology. The novel affimer technology (developed by Avacta®) in our biosensor sets it apart from commercially available sensors. Although affimers have been used in sensing applications before, they have been rarely used in microcantilever technology like in our sensor. It also appears that affimers specific to valproate molecules have never been made before, however this assumption could be due to limited literature available online for this niche application.
To support this novel chemical technique, it should also be noted that the microfluidic design is also unique, mixing very modern pumping technology with a rarely seen droplet manipulation design. The use of SU-8 as the material of the microcantilever is rarely seen on the market commercially compared the more common silicon.
The idea and decision to focus on microcantilever applications was solely made by the team itself, along with all research and design processes being conducted by the team. Tony, our supervisor helped to direct us towards the affimer technology route and Stuart and Abi at TTP gave us advice on our cartridge design, however, the main areas of cartridge and flow mechanisms where thought up and developed by our mechanical engineering students. The physical transduction and development of the SU-8 and gold nanoparticle surface was original thought from the bioengineers in our team. Furthermore, the total design and creation of our app were all carried out by Konrad; and the website was produced by Shruti and Simran, our bioengineers. All drawings of the sensor and cartridge where produced by Nic, and the affimer images taken by our chemists using PyMol.
Finally, we think it should be noted that the use of a microcantilever also allows the device to be easily upgraded and maintained, and with developed affimer technology the sensor can be adapted for other uses, including sensing for a variety of drugs in the blood. This could make it one of the few biosensors that can be used by many kinds of patients just by swapping the cartridges, whereas most conventional biosensors are directed at one condition.



Signed by: Tony Cass (Supervisor), Annabel Chatwin (Team Captain) and Poppy Tobolski (Team Captain)

4.2 Supervisor document

The *Minerva* team has demonstrated novelty and originality in a number of respects. Early on the team chose a microcantilever based sensing format and, realising that current microcantilever devices were very much laboratory-based instruments, identified that alternative materials for the cantilevers would be necessary. In this regard they propose replacing expensive silicon structures with cheaper and more suitable polymer materials which could be manufactured at scale and with more suitable properties for routine VPA testing. All of these ideas were worked up by the team with little input from me.
When it came to the molecular recognition aspects their initial thoughts were to use a VPA specific antibody and I encouraged them to consider alternative scaffolds such as anticalins, nanobodies, affimers and aptamers as well as molecularly imprinted polymers. The team then considered all of these and based on the literature and their own assessments made their choice.
Finally, in thinking about sample presentation the team decided on a fluidic cartridge and I suggested they look at droplet fluidics and they came up with original designs that integrated sample handling, sensing and display.
In summary *Minerva* have invented a system that shows originality in the choice of individual components and their integration into the final device.



Signed by: Tony Cass (Supervisor), Annabel Chatwin (Team Captain), Poppy Tobolski (Team Captain)

5. Translation Potential

5.1 Business Model Canvas

Problem	Solution	Unique value proposition	Unfair advantage	Customer segments
More accurate Therapeutic Drug Modelling requires frequent tests. Doctors would like to be sure patients are taking their medicine More frequent tests requires frequent appointments which may eat into school time or rest time.	Electrical biosensor and cartridges (in bulk) sold to schools who provide testing service to pupils with epilepsy.	Selling the device to a school so as to shift the economic burden from individuals to institutions with bigger budgets and potential subsidisation. Use of app as main user interface allows remote access and connection between doctor and patient, and reduces device costs, as well as accommodating future growth into new ventures with same device.	Support from world leading university Free advertisement of device through Sensus competition.	School boards for purchase, school nurses for operation. Pupils and doctors will need to be convinced to participate.
Existing alternatives Roche Cobras Assay. Requires medical expertise and difficult to use equipment	**Key metrics** Device sales Cartridge uses App downloads Amount of inputs into data log.	**High level concept** Bringing the doctor's office to the school nurse's office	**Channels** Recommendation from medical professionals Sales pitches to promote the device at Medical device Events. Sales pitches directly to schools. Social media	**Early adopters** Doctors with patients would be recruited to adopt the device early in development and continue using while promoting it. Afterward secondary schools are likely to be early adopters as they have a larger amount of students and likely to have more use for the device.
Cost structure Cost Driven - key to reduce microcantilever manufacture costs Economy of Scope – true value of device will be realised when new applications implemented Fixed Cost			**Revenue streams** Initial device sales Cartridge replenishment in bulk Device repair/maintenance In-app advertising	

5.2 Stakeholder Desirability

Valproate is used to treat seizures found in roughly half of all epilepsy cases, making our product relevant to a large portion of patients, who would be user stakeholders. We conducted interviews to understand how to target the product more effectively. We interviewed a doctor, one Dougall McCorry, about his opinions on the matter as a doctor with at least 1000 patients with epilepsy by his count. He told us that a valproate biosensor could be useful as a source of evidence as to whether a patient was taking their medication, as many don't, and to aid conversation between patient and doctor. Additionally, having such a device closer to the patient could help those who have difficulties reaching their doctor, particularly relevant during the current pandemic, but also applicable to patients who can't drive or risk seizures en route, however the usefulness of such a device would depend on it being easy to use by a non-professional person.

We also interviewed a young patient with epilepsy, Tom Rugman, with question related to a value proposition targeted at schools. He told us that appointments often took time off school, and that he thought having school take charge of the service would be good, as they already deal with certain vaccinations and have a school nurse available to help pupils. He talked about possibly expanding a complementary app to aid with other aspects of life with epilepsy, becoming a more general lifestyle app.

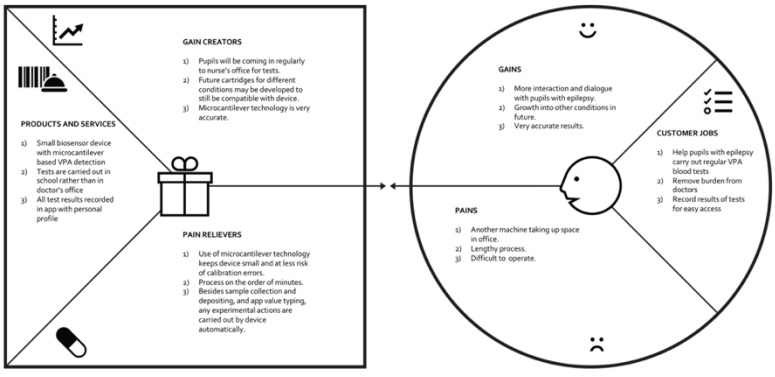


Figure 9: Value proposition canvas

We thus designed a value proposition aimed at schools as our direct clients, with pupils with epilepsy using the device alongside their school nurse. Schools have bigger budgets than individuals and can more easily afford to invest in our product, while also having a direct line of communication with various potential users (their pupils) thus making the necessary scale of our marketing strategy a little more manageable. Our value proposition can be described as "Help pupils with epilepsy by providing blood tests during school hours". Its merits are shown in the canvas.

5.3 Business Feasibility

During early development the key activity will be developing the assay, which will require building prototypes of the device using ready-made components from other biotech companies and, crucially, a licensing agreement with Avacta® to use affimers in a commercial product. During this stage hospitals would be needed to help beta test the prototype and inform further research and development, potentially with the consulting aid of companies such as TTP, who have consulted us during this project.

The product would then be developed into a more ergonomic form for our school focused value proposition, with collaboration with custom part manufacturers, and an effective marketing campaign. This would be carried out using events and conventions attended by schools, and even competitions similar to Sensus. Approvals would need to be gained from national regulatory bodies such as the MHRA, requiring clinical trials. We would also begin to sell to medical professionals closer to patients such as GPs and try to get our app published on the NHS app library, gaining credibility and helping to promote the product. Once established after a few years we would grow into other markets and ventures, having carried out relevant R&D since the beginning. Our microcantilever can be used for monitoring other conditions simply by changing the affimers, increasing our total market and adding value to our business. This would require even further collaboration with companies such as Avacta®.

Successful commercialisation depends on early investments to cover development costs. Investors could depend on a relatively quick break-even time and a large potential for future growth to dramatically pay back any initial setbacks. Additionally, the UK government could be relied upon to either subsidise our research and therefore cover some costs, or to subsidise schools and hospitals purchasing our products, thus making our sales easier. Small strategic alliances would also be formed with other companies like Avacta® to develop individual biosensor components.

5.4 Financial Viability

Unfortunately, the unavailability of labs has made cost and revenue projection even harder than usual. Regarding revenue, we have reduced profit from initial device purchase, aiming to make more from cartridge sales and subscription. The simplicity of the device allows for a low selling price, which makes the initial sale easier.

Product/service	Device	Cartridge	App/website
Price (£)	40	225	0.99 per month
Notes	100% markup	50% markup	Covered by school/insurance

Table 1: Products/services Selling Prices

Research and development costs would go towards things like having access to a laboratory, prototyping materials and machines, reagents and blood samples, purchasing PPE and CAD software. General and Administrative costs would go towards things like wages and office rent. The cost of goods and manufacturing, which would begin to have to be considered during early prototype development, would have to cover initial injection mould purchases, materials for mass printing of the chips, bulk purchase of reagents, quality control checks, and shipping costs (using business prices from Royal Mail).

These costs are all worth facing for the different elements of our business strategy. We aim to grow by:

- maintaining a technological edge over existing assays that gives our device the ability to take accurate, reliable readings in under 5 minutes.

- Keeping our product easy to use, and thus popular with individual patients.
- Maintaining our development activity with the ultimate goal of expanding into other ventures and market segments.

In the UK there are 20,832 primary schools and 4,188 secondary schools [13], with on average 1 and 5 pupils with epilepsy each respectively[14]. Half of epilepsy cases cause seizures treated by valproate, but it's not recommended for women and girls. Therefore it can be assumed that roughly a quarter of the school population with epilepsy could be in need of valproate targeted TDM. We take as estimate that one user would go through 13 cartridges a year (a little more than once a month). As for our clinic directed strategy, there are 7613, 935, and 430 GPs in England [15] Scotland [16] and Wales [17] respectively, a total of 8978. We take as estimate that on average each GP has one relevant patient (likely a conservative estimate).

	Year 1	Year 2	Year 3
Revenues			
Device	0	805,216	603,912
Cartridge	0	1,071,744	1,875,553
App	0	13,738	24,042
Total	0	1,890,698	2,503,506
Costs			
G&A	600,680	867,280	833,420
COGS	596,406	1,303,465	1,337,292
R&D	152,765	149,765	150,765
Sales & Marketing	961,465	961,465	961,465
Total	2,311,316	2,414,695	2,449,523
Profit	-2,311,316	-523,997	53,984

Table 2: Cost Projection

Both these models are very rough. For example, there are more types of schools then primary or secondary, and there are more clinics than GPs. However, taking these estimates as representative for now, and assuming a slow geometric rate of growth, Table shows a forecast of profit for the first few years, assuming around 10% of the possible entire market segment has been sold to in the first year on the market, which would be necessary to achieve break even by the third year. To assess the viability of the venture the LTV has been calculated for a pupil after 6 years in school and compared to an average value of the CAC for electronic devices of £140 [18]. Guidelines suggest that the LTV/CAC ratio should be at least 3 [19]. Ours is about 14, which is very good, and also gives room for some real-life setbacks.

After break-even we'd begin growth of the company and dedicate R&D to finding more applications of the device and the chip technology. Ideally an application would be found that could merit sales direct to individuals, increasing profits from device sales. Marketing would be easier since we'd have an established presence in schools and clinics.

6. Team and Support

6.1 Team members

All members of the team helped and were involved in the creation and development of all entrepreneurship assignments and feedback moment presentations, along with the production of the team results document and pitch slides.

Annabel Chatwin – Joint team captain and member of the Chemistry team thus helping in the research and development of the affimer based technology lead (given from Tony). Annabel was the main point of correspondence to the SensUs organisation and other major contacts including Tony and Stuart at TTP. Also, vlog video editor and creativity pitch speaker.

Poppy Tobolski – Joint team captain and member of the Chemistry team, thus also helping in the research of the affimer based technology. Poppy was also in charge of the Social Media account helping us to reach out our message into the public domain as well as using it to spread a survey to help our design suit many people's wants. Poppy also helped with and featured heavily in the making of the vlog.

Lucy Clift – Member of the Chemistry team conducting many literature reviews and helping in the research and development of the affimer based technology. Lucy also played a major role in the translation potential final pitch, in both the writing of it and as one of the two speakers.

Simran Sandhu – Member of the bioengineering team, playing a major role in the development of the physical sensing principle microcantilever, and development of SU-8 and gold surfaces. Simran did all the video editing for our three innovation days pitches and is one of the speakers in the creativity pitch.

Shruti Shikhare – Member of the bioengineering team, thus helping as above in the development of the physical sensing principle microcantilever, and development of SU-8 and gold surfaces. Shruti was also in charge of the whole website programming and development from start to finish.

Mohit Gurnani Rajesh – Member of the electrical engineering team helping in the development of the microcantilever surface and circuit and also website/app design.

Sushanth Kolluru – Member of the electrical engineering team helping in the development of the microcantilever surface and circuit and also website/app design.

Arjun Ananth – Member of the electrical engineering team helping in the development of the microcantilever surface and circuit and also website/app design.

Konrad Hohendorf – Member of the mechanical engineering team and in charge of reader instrument and user interaction. Konrad was responsible for all app programming and will also be performing our one-minute pitch.

Nicolas Geiseler Toran – Member of the mechanical engineering team specialising in cartridge design, microfluidics and droplet manipulation design. Nic played a pivotal role in the development of our translational potential business plan and will be a speaker in the pitch. Along with all this, nic has used his technical drawing skills to draw many images of how our cartridge and device will look and also designed our iconic *Minerva* logo.

6.2 People who have given support

Professor Tony Cass - Tony has given us many intuitive ideas to overcome challenges faced in the biochemistry aspect of the project, such as helping guide us towards novel chemical techniques such as affirmers and aptamers as well as molecularly imprinted polymers. Tony also helped the mechanical engineers, suggesting they look at droplet mechanics. Overall, we would like to thank Tony for all the help and support he has given us.

Dr Stuart Lowe, Dr Wenshu Xu, and Dr Abi Graham from TTP gave us valuable insights into the feasibility of our design and business model. They were easily reachable and their expertise in the field was much appreciated. We benefitted greatly from a Skype call meeting with them.

We would also like to give thanks to **Dr Dougall McCorry and Tom Rugman** for allowing themselves to be interviewed and giving us their valuable opinions and insights.

Finally, thanks go to last year's England team ***Joint Venture***. Learning from their experience assisted us on overcoming challenges and deadlines.

6.3 Sponsors

Although there was no requirement to be financially sponsored this year, as the labs have been closed (thus there was no building of a physical biosensor), we received great support and advice from **TTP**.

7. Final remarks

Despite not having any access to labs this summer and therefore the project being held remotely at home rather than in London, we are very proud of what has been achieved by our team. We are excited by the ambitious and creative design we have made and, supported by a solid business plan, we are confident our sensor will be a success in years to come. Additionally, with the use of varied affimer technology and replaceable cartridges our sensor has the potential to be developed for detection of a variety of drugs and molecules, not only valproate, which we believe makes it stand out from the sensors already commercially available. Finally, we would like to send our thanks to the SensUs organisation and community for giving us the opportunity to participate in such a worthwhile and influential experience. With that, we would like to leave you with a quote from Sushanth, when asked to summarise his motivation for the project:

"I believe the SensUs project will provide me with an opportunity to work on something that can could play a part in improving the quality of life for millions. I am further motivated by the success of previous SensUs project entries, which have pushed their respective fields forward." Sushanth, EEE

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