SOS-E (Survivor Observation System - Ebola)

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Problem

- Over **10,000** Ebola survivors return home from Ebola Treatment Units to deal with the possible and relatively **unknown** long-term health effects of this virus.
- Many survivors are experiencing “Post-Ebola Syndrome” - muscle deterioration, ocular problems, hypertension, diabetes, and mental health problems.
- It is **unknown** how long these conditions last or when they can even appear in the survivors.
- It is **unknown** whether or not the virus is **alive** and hiding in the bodies of all survivors.
- Both survivors and health care workers face **stigma**, as people are afraid of contracting the virus through them.
- With a lack of trained medical staff in regions of Ebola outbreak, **tracking survivors** and ensuring they receive adequate treatment is not easy. While there are Ebola missions being undertaken across Guinea, Sierra Leone, and Liberia, it is *not enough* to track the progress of the survivors’ health.

Background

- From literature review and testaments from survivors, we found multiple cases of the virus situated in the eyes and joints/muscles;
- Our team researched viable ways to track the progression of the virus and consulted with already existing technology doing the same;
- Ocular issues (uveitis, blindness) are often seen in Ebola survivors and can arise at any point after recovery;
- EBOV GP (Ebola virus glycoprotein), a fusion protein that mediates cell fusion of EBOV onto endosomal membrane to cause infection, are cleaved by cathepsins to turn GP into active form. Low pH promotes fusion through well-known pH dependent activity of cathepsins.

Our goal is to develop a technology based Ebola survivor observation system that is cost-efficient, effective at communicating changes in survivors' bodies, and discreet at monitoring health.

Hypotheses

1. Detectable changes in the **pH level of the blood stream** may indicate an **increase in EBOV GP fusion**, if occurring, which in turn indicates EBOV fusing envelope membrane within endosomal membrane to cause infection.

2. High fluctuations in the **intraocular pressure** of the eye may indicate the **presence of EBOV in the aqueous humour.**

3. **Detectable antibody-antigen linkages** in the tear film of the eye indicates that the survivor is hosting the **live, transmittable virus.**

Overview of Solution

- We designed a contact lens and wristband system that would detect the presence of EBOV and monitor viral levels.
- **Contact Lens Component** - detects and quantifies presence of EBOV in the eye.
  - Intraocular Pressure (IOP) Sensor
  - Equine IgG Antibody Serum
  - Powered by solar cells
- **Wristband** - measures pH changes in blood
- **Bluetooth communication** between contact lens and wristband
- Wristband displays readings in colors: green, blue, yellow, red
  - **Green** - all inputs are normal
  - **Blue** - pH of blood is more acidic than normal
  - **Yellow** - Abnormality in IOP
  - **Red** - Antibody-Antigen linkage detected → patient SHOULD visit clinic

Lens Component - Intraocular Pressure (IOP)

IOP measuring component is based on the SENSIMED Triggerfish Technology [5]. The contact lenses bear two main components that aid in IOP change detection:

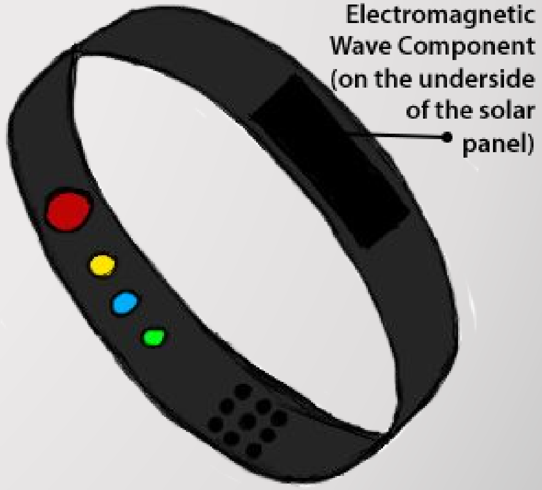
- **Strain Gauge:** measures circumferential curvature in the corneoscleral region related to change in IOP.
  - A piezo-resistive strain gauge produces a variable resistance depending on the radius of the user's eye, which is translated to voltage by an appropriately designed Wheatstone Bridge circuit. Changes are measured over a period of 30 seconds at intervals of 10 minutes.
- **Radio Frequency Transmitter:** sends signals via Bluetooth to the Wristband regarding changes in IOP.
  - Values obtained are in electronic units (millivolt) and hence on an increase beyond 40mm of Hg; the transmitter receives a signal from the wristband to release the serum.

Lens Component - Immunoglobulin G Antibody Serum

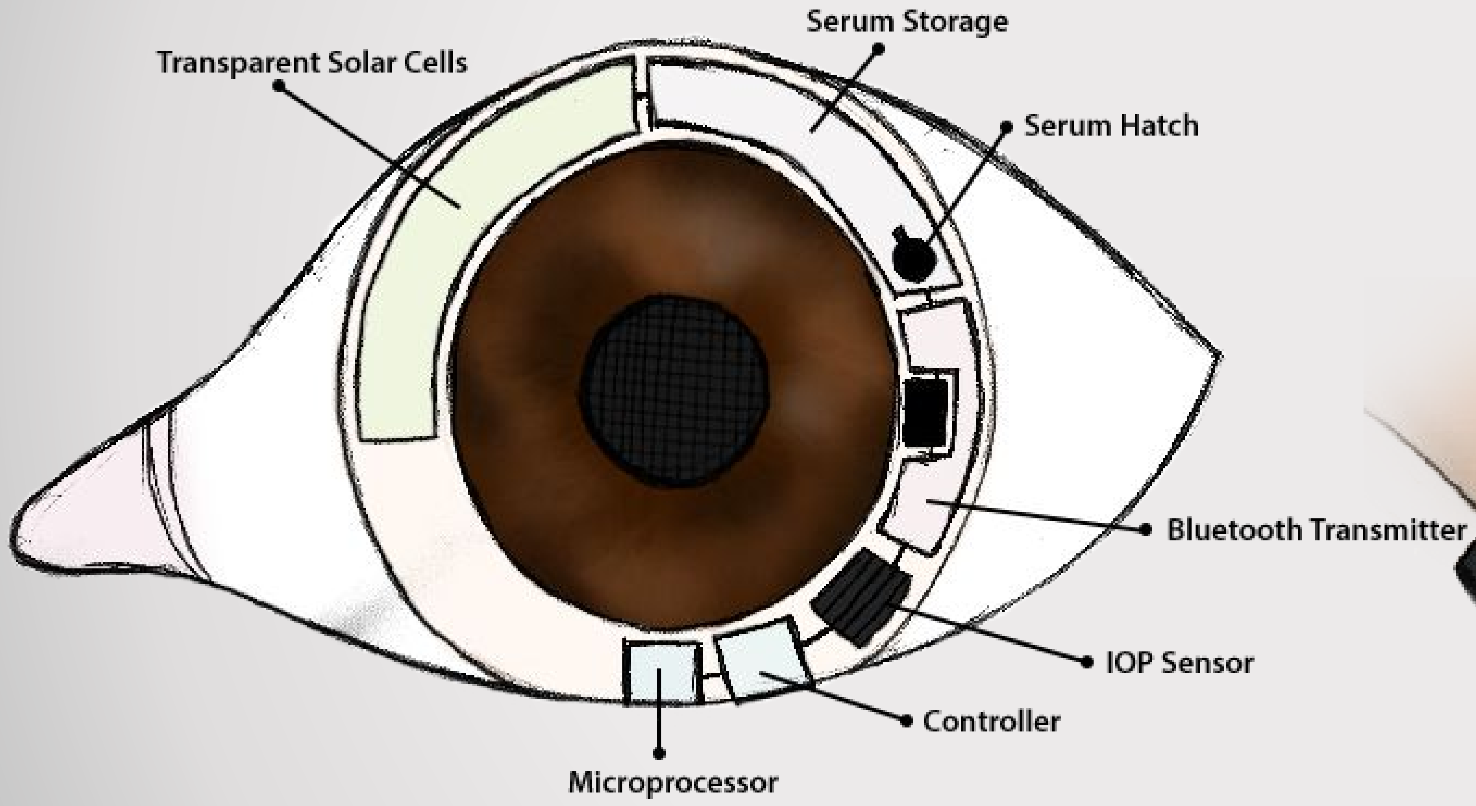
- This serum will contain the **equine IgG antibody.** [2]
- The serum will be refilled in the lens when kept in the case overnight.
- The human eye's tear fluid includes lysozymes. When the lenses come into contact with the eye, the serum will be periodically released using nanodiamond technology. [4]
- It will be contained in a layer of the lens - the wiring will open a small hatch from which the serum will be pushed out.
- This will be done ONLY when the IOP increases to a level beyond 40 mm of Hg.
- Using the pre-existing knowledge of the EBOV protein chain, we will detect the antibody-antigen linkage. This would be carried out previously in a lab, and the result would be coded onto the sensor.
- In one layer of the lens, there will be transparent solar cells [5] wired to the Bluetooth component and the microprocessors. Circuitry will be wired through all layers, connecting the hatch, IOP sensor, bluetooth, and cells together.

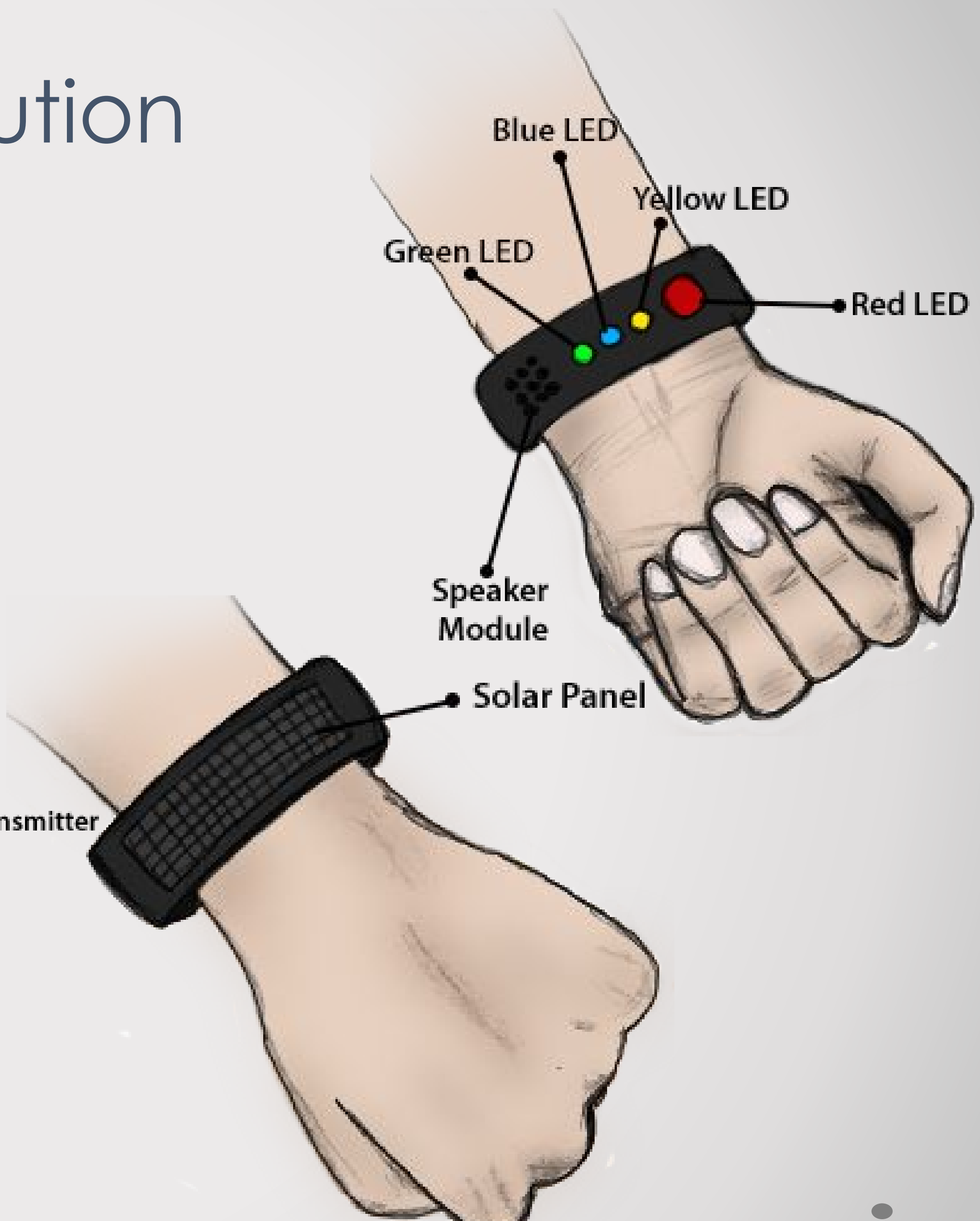
Wristband Component

- Acidic pH levels lead to increased fusion of the EBOV GP while still pH-dependant.
- The wristband will measure the pH of the blood. This will be done by flashing electromagnetic waves through skin and tissue to be able to detect the light signature of oxygen molecules.
- It will be made of 2-shot injection molded polycarbonate and silicone rubber, as that makes it suitable for prolonged wear as well as making it waterproof and unaffected by perspiration.
- There will be three default sizes, and each size will have three different adjustment levels for the survivor to have it fit as comfortably as possible. This adjustment will be done through basic metal clasps and three equally spaced holes in the material to hook on to.
- It will communicate with the contact lenses through a bluetooth chip that will be embedded in the wrist band. Microprocessors will be controlling the logical component of the wristband that is outlined in the next slide.
- The wristband will be solar-powered, with a solar panel on the outer side. Since our model will be using more energy than an analog watch, continued exposure to the sun will assure usage for days.



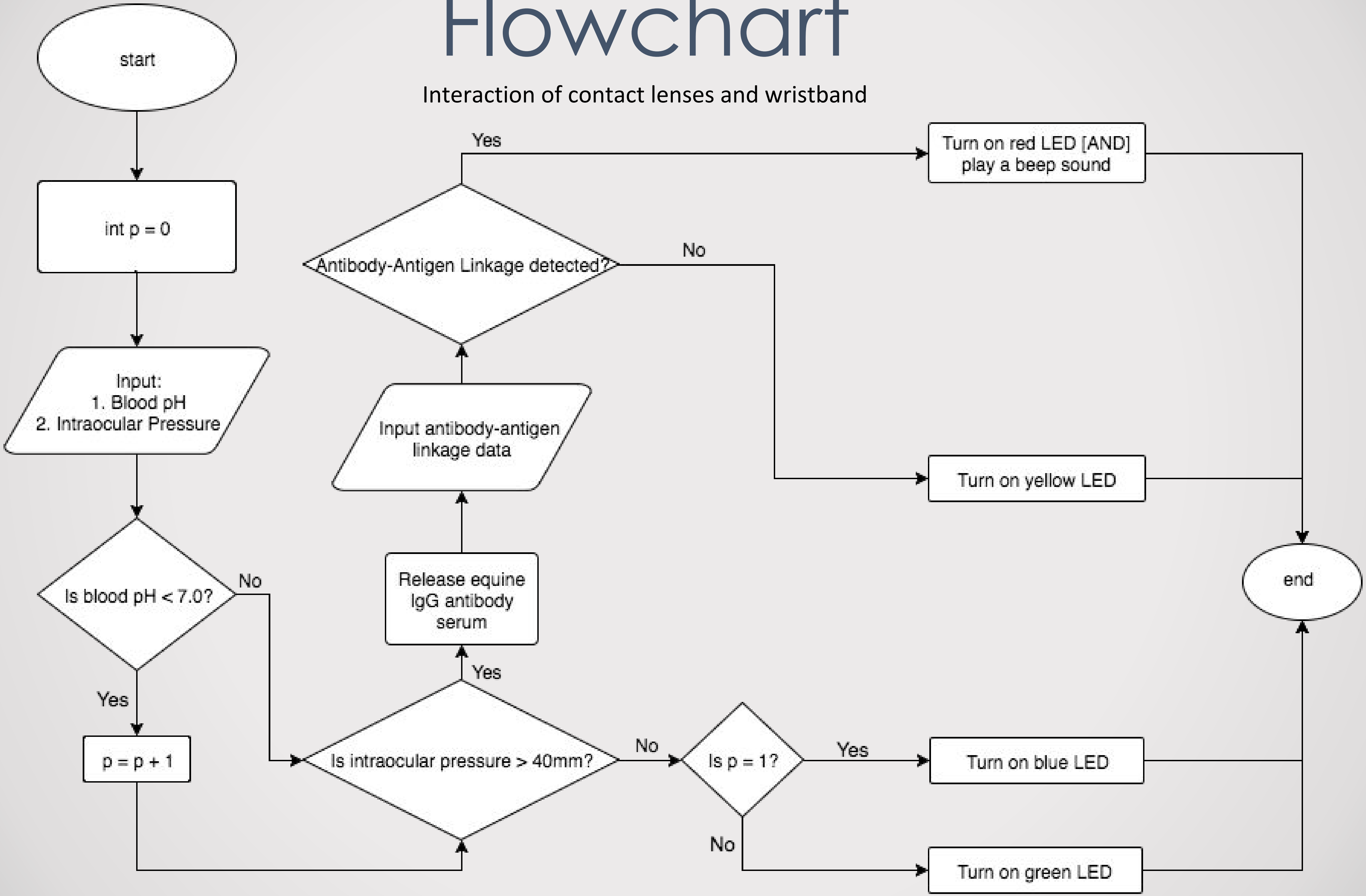
Design Sketches of Our Solution





Flowchart

Interaction of contact lenses and wristband



Cost Prediction

Wristband Component

(Commercial, Non-Bulk prices)

Polycarbonate and Silicone Rubber - $2.00

Bluetooth Chip - $5.00

Microcontroller - $5.00

LEDs (x3) - $4.00

Speaker - $2.00

Development of Electromagnetic component - $5.00 - $10.00

Solar panel - $3.00

Estimated total - $26.00 - $31.00

Possible, post-bulk total - $13.00 - $15.50

Contact Lens Component

(Commercial, Non-Bulk prices)

IOP Sensor- Unknown *Commercial market value estimated to be $400 USD

Equine Antibody Serum- *Low Cost*[2] *Refer to Citations

Bluetooth Chip- $5.00

Silicone Hydrogel Lens - $20.00-$25.00

Hand Sanitizer (+60% alcohol) - $3.00

Estimated total - ($28.00 + Low Cost Equine Antibody Serum + IOP Sensor)

Possible Post-Bulk Sum Total (Wristband + Contact Lens)= $41 + Low Cost Equine Antibody Serum + IOP Sensor

Methods to Collect Data & Feedback

First, after coming up with a preliminary solution, we conducted a survey to **gauge market interest** and to collect feedback. This is the link to our first survey: https://tinyurl.com/l2h76ph

a. This is our response spreadsheet: https://tinyurl.com/kzmoumn

b. Consumers are interested in:

   i. Discrete tracking

   ii. Self-checking status of virus

   iii. Easy usability of system

   iv. Easy understanding of results

   v. Cost - not willing to consider the product if priced above $100 if minimum wage is $60

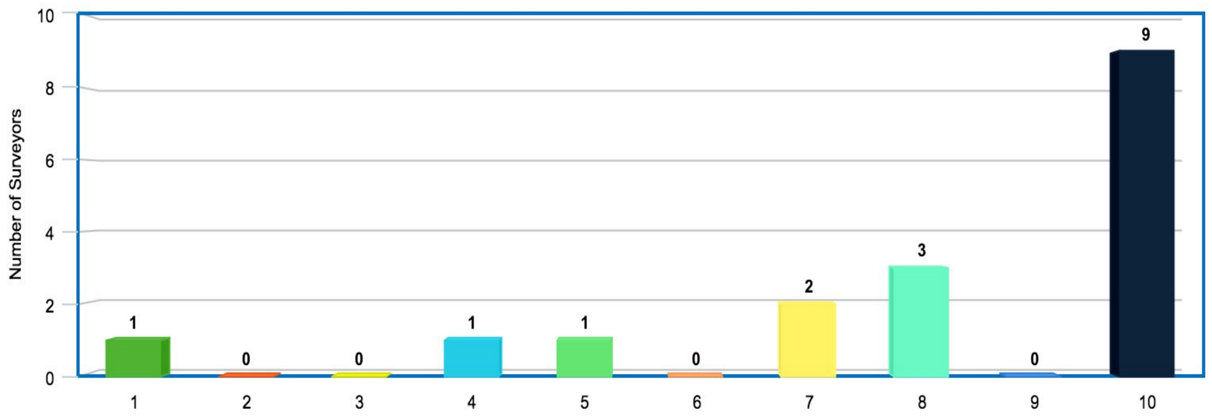
   vi. Sanitation

After refining our solution, we consulted experts using a follow-up survey and asking additional questions. This is the link to our second survey: https://tinyurl.com/lvcg375

a. This is our response spreadsheet: https://tinyurl.com/k5fs2wp

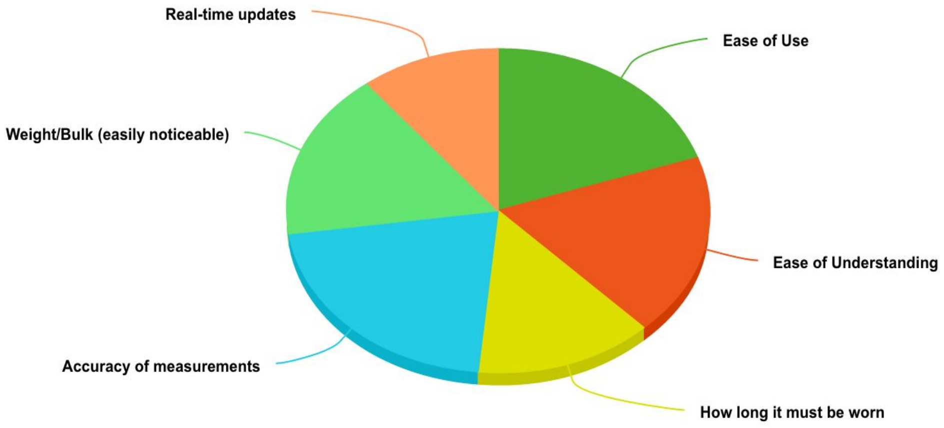
Results - Survey #1 Statistics

How important would you rate tracking your health in a discrete way if you were an Ebola Virus (EBOV) survivor?

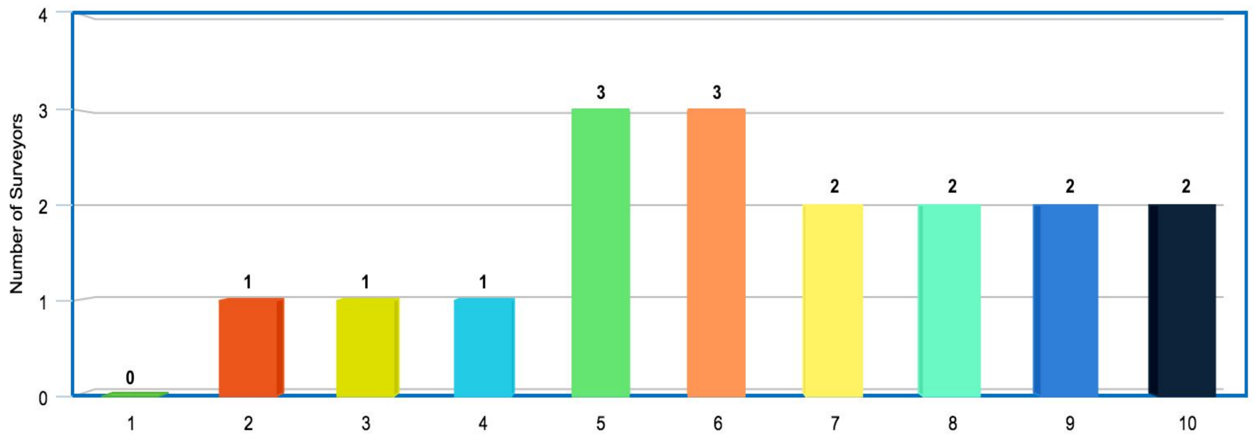


Rating (out of 10 where 10 is most important)

What factors would you consider while investing in a product to track vital inputs regarding the presence of the EBOV in your body?

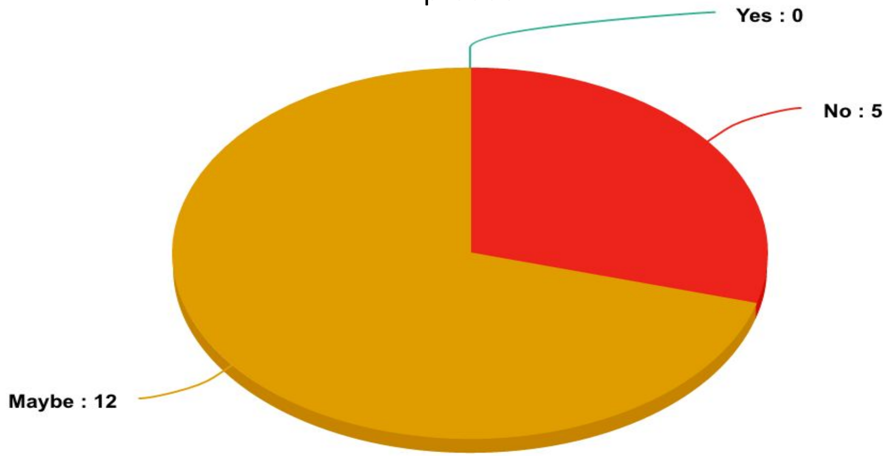


Would potential users mind wearing contact lenses?

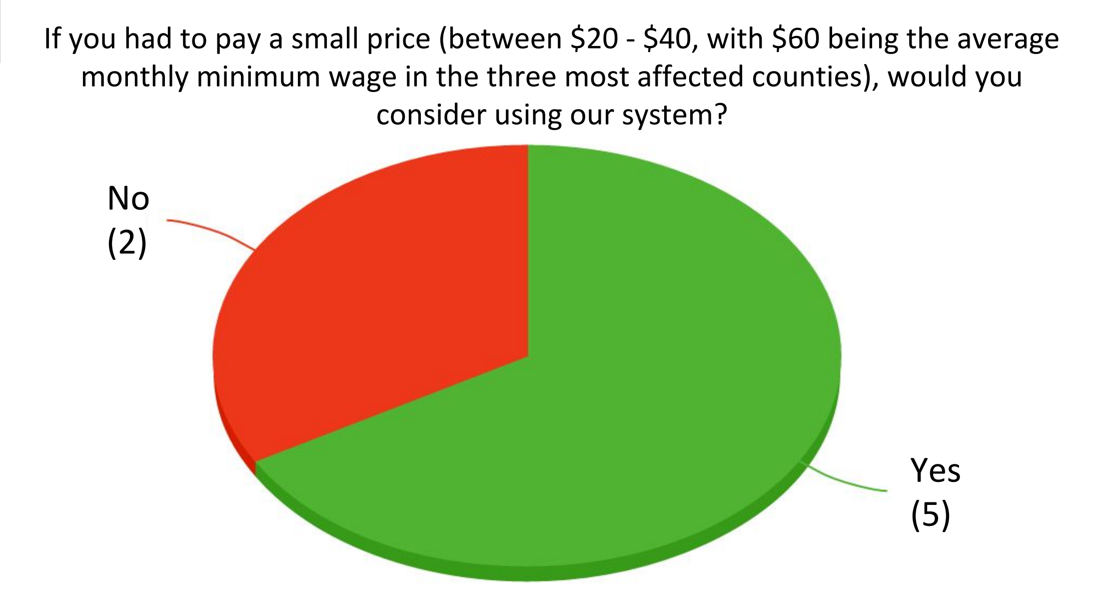


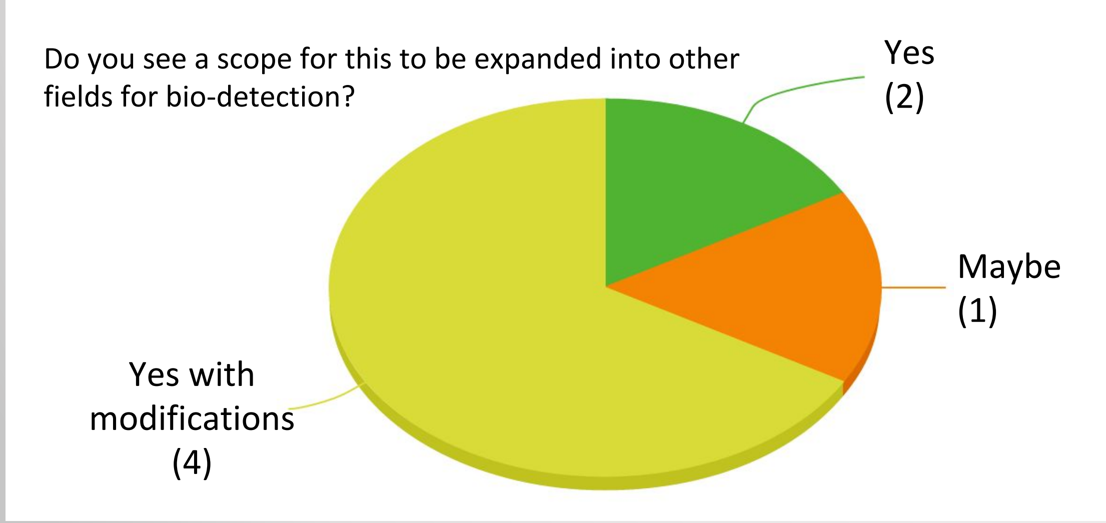
Rating (out of 10 where 10 is don't mind at all)

Would you be willing to pay more than USD $200 for this long-term product?



Results - Survey #2 Statistics





General Feedback/Comments/Suggestions:

- Generally, all surveyors said they would feel comfortable wearing the contact lenses for longer hours considering they include a IOP detecting component, pouch for antibody-antigen detecting serum and solar cells for powering the lens
- 85.7% of surveyors said they would be willing to use our system if they were an Ebola survivor
- Most surveyors thought our system was innovative as a whole but had concerns with implementation: cost, distance of health clinic centers from survivors, and communication of data

Next Steps

1. **<u>Lab Testing</u>**
   a. This should be performed for the IOP sensor, to test accuracy, as well as for antibody-antigen linkage detection. The exact results would be programmed on to the sensors and microprocessors for the logical flow of the product.
2. **<u>Cost Determination</u>**
   a. Purchasing of components in bulk would subsidize the costs. Additionally, as this product does lie under public health, we will be expecting subsidies on the behalf of the department of health in these countries to make the product more affordable.
3. **<u>Saline solution and Hand Sanitizer</u>**
   a. This also allows us to monitor if the patient is using the lenses - they will have to check in for more solution/sanitizer every month if used as directed. An approved hand sanitizer with +60% alcohol would assure sanitation while putting on and removing the lenses to avoid any infections.
4. **<u>Educating the Survivors</u>**
   a. Since it is extremely important for survivors to keep track of the status of the virus, we will stress the importance of monitoring their health to all survivors.

Further Directions

(Based on region or different subsidies, here are additional options that are also viable)

Further Parameters that Could Be Done in Clinics:

- Eye drop solution to induce pH change and detect presence of Ebola glycoprotein fusion
- Integrate artificial tetherin to detect presence of EBOV
- Eye drop solution containing IgG antibody to detect antibody-antigen fusion

Potential Modifications:

- RGP (Rigid Gas Permeable Lens) instead of silicone hydrogel for more durable and up to 2 years usage → more expensive
- Consider other ways to detect equine IgG antibody-antigen linkage
- Using body movement/body heat to power wristband → another energy source besides solar power

Further Applications:

- Smartphone App for doctors to monitor and record survivors' health
- Our system could be used to track discrepancies in health/other viruses

Existing Technologies

Contact Lens

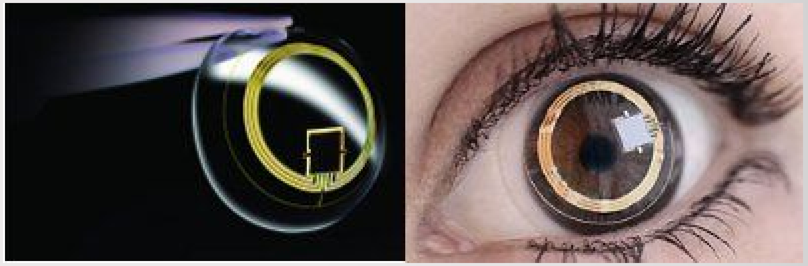
- SENSIMED Triggerfish IOP Sensor [5]
- Glaucoma drug releasing Contacts [4]
- Photodetectors on Contact lenses to harvest light energy for power.[6]

Eyedrop Solution

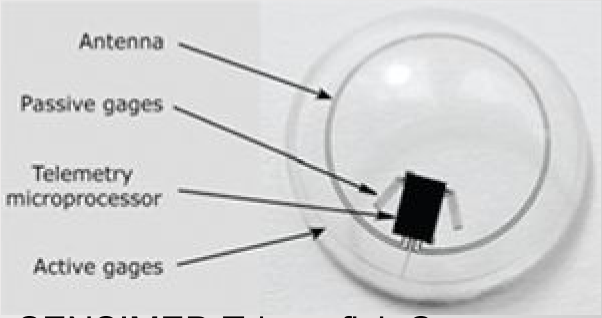
- Inducing pH change → tropicamide and phenylephrine[8]

FitBit Flex 2 Wristband

- Sports wristband made of flexible, durable bio elastomer



SENSIMED Triggerfish



SENSIMED Triggerfish Sensor

Citations

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Thank You

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- SENSIMED Triggerfish for IOP pressure sensor analysis and feedback
- Experts and respondents to our surveys