Drink Guardian: A Two-Step Verification System for the Detection of Sedatives in Alcoholic Beverages

Product Design

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ABSTRACT

About 20 million students will attend college and universities in the fall of 2020.[1] For many, college should be some of the most exciting years of young adult lives, lurking beneath the excitement hides a dangerous national issue—drug-facilitated sexual assault in college communities. According to a study conducted by the American Addiction Centers, out of people who have had their drink spiked, 52% had their drink spiked for the first time in college[2], while more than half of college sexual assault cases occured in the first semester.[2]

To combat this issue, and hopefully decrease the occurrence of drug-facilitated sexual assault in college communities, we propose Drink Guardian: a robust drug-detecting device that continuously monitors a user's drink, and has the ability to signal both the user and a sober friend or partner upon detection of a drug. In particular, we plan to accurately determine the presence of Rohypnol, a common date-rape drug, as well as limit false negative results using both fluorescence and electrochemical methods. The fluorescence test will detect two peaks at 250 and 315 nm for unprotonated Rohypnol, or a single peak at 280 nm for protonated Rohypnol.[3] The electrochemical test, on the other hand, will look for a current peak at around -0.3 V which lies between Rohypnol's first oxidation and second reduction reaction equilibrium.[4] When both tests are positive, a notification and vibration will be sent to the user and a sober friend of choice, via bluetooth from Drink Guardian to their smartphones.

This report will further detail Drink Guardian's product specifications and development, manufacturing process, and financial analysis. With our proposed manufacturing process, we will produce 1,132 devices a day to be able to launch 293,500 devices in our first year on the market. We expect universities to cover the $100 cost of Drink Guardian and provide our devices to students. Moreover, the cost of fixing broken equipment will be provided through a warranty, as it is built into our business costs. Based on our financial analysis we predict to break even after roughly five years.

TABLE OF CONTENTS

INTRODUCTION

Drug-facilitated sexual assault (DFSA) refers to the intentional drugging of a victim in order to compromise their ability to consent to sexual activity. Although data detailing the frequency of DFSA remains widely unavailable due to a number of reasons, the seriousness and prevalence of this issue is undoubtedly present.[5] Among those that are affected, college students make up a percentage of people who have been assaulted due to incapacitation from a foreign substance. According to the American Addiction Centers, out of people who have had their drink spiked, 52% of those people had their drink spiked for the first time in college, and the location with the highest occurrence of this activity was at a house party.[2] In addition, more than 50% of college sexual assault cases occur in the first semester alone, as reported by RAINN.[6] Therefore, with an estimated total of more than 20 million students entering college in the next couple of years, there is a great concern for the increasing pervasiveness of these incidents.[1]

Although there are products available on the market to combat this issue, these efforts have been widely unsuccessful. In general, these products will notify a potential victim if their drink has been spiked so long as they choose to perform a manual test on it. While the detection methods these devices employ do work well, there are several other constraints which have limited their ability to serve their full purpose in protecting the user. In response to this, our team proposes an alternative known as Drink Guardian which seeks to address those constraints by providing the user a convenient, reusable device that performs continuous and accurate testing by means of fluorescent spectroscopy and electrochemical techniques.

BACKGROUND

The following section will detail the specific detection parameters a successful drug testing kit would need to have, how previous products have attempted to meet these parameters, and how our product seeks to meet these parameters.

Target Detection

With the prevalence of drug-facilitated sexual assault cases rising on college campuses, our product aims to provide a preventative testing system against the traumatic and destructive consequences that result from on-campus drugging. To begin marking the parameters that our device tests for, we found a comprehensive list of “club drugs” which indicated that the most

commonly used drugs used for sexual assault in a party are flunitrazepam (Rohypnol), gamma-hydroxybutyric acid (GHB), gamma-butyrolactone (GBL), and ketamine.[7] Because these drugs are colorless and odorless, the victim of a drug related sexual assault is often unaware of their drink's contamination.

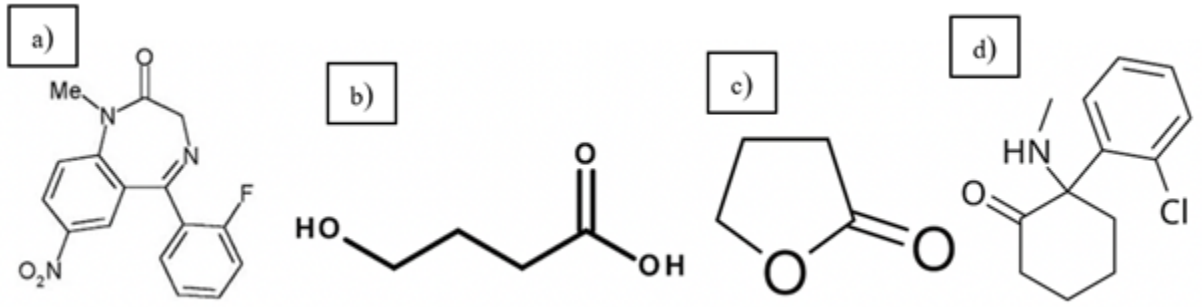

Figure 1: Chemical Structures of a) Flunitrazepam (Rohypnol), b) Gamma-Hydroxybutyric Acid (GHB), c) Gamma-Butyrolactone (GBL), and d) Ketamine

A successful testing device would have to accurately assess the contamination of a spiked beverage and effectively communicate this information to a possible victim in a hectic party setting. This party setting would likely cause victims to be physically unable to conduct a complex chemical test on their drink, so we concluded the best approach would be to design a device that automatically monitors and reports drink contamination. When considering what the aforementioned date rape drugs shown in Figure 1 have in common, we found that each of them are organic compounds that have specific redox chemistry and absorption spectra. Therefore, we proposed the idea of Drink Guardian, a continuously active testing device that tests for drink contamination using both redox chemistry and absorption spectra. Drink Guardian would specifically target flunitrazepam, or Rohypnol, for now, but our device does have the potential to target other substances. The minimum dosage needed to prompt symptoms from a sample of flunitrazepam is 400 ng/mL[3], so our device's testing methods are designed to meet that detection target.

Competitive Landscape

To consider the possible market adoption and competitors of our product, we did a comprehensive search of similar testing devices. Devices such as SipChip[8], DrinkSavvy[9], SmartStraw[10], and Pd.Id[11] all had novel methods for testing for contaminants, but almost none of them have made any significant strides in establishing a significant customer base. While SipChip, DrinkSavvy, and SmartStraw all have patents for their devices (Patents 10024873, 9285352B2, and 20060144730A1 respectively), the only device to actually make it to market so far is Undercover Colors' SipChip. SipChip is a disposable tablet that uses a lateral flow assay to determine the contamination of drugs such as ketamine and GHB. However, SipChip has some deficiencies such as its lack of reusability. Moreover, the other devices have missing functions which are incorporated in our product. We have outlined these functions through our comparison matrix in Table 1. One important detail to note is the presence of a question mark under the function of testing multiple drugs for our product. While our current design specifically targets Rohypnol, the spectrophotometric and electrochemical tests our device employs can be fit to match other drugs. After considering our products considerable advantages over the relatively sparse network of competitors, we concluded that it has the potential for a significant initial market adoption rate.

Table 1: Comparison Matrix for Patents with Similar Functions to Drink Guardian

	Reusability	**Tests Multiple Drugs**	**Multiple Tests**	**Constant Monitoring**	**Signals Sober Partner**
Drink Guardian	✔	?	✔	✔	✔
Pd. Id	✔	✔	X	X	X
SipChip	X	✔	X	X	X
DrinkSavvy	X	X	X	✔	X
Smart Straw	X	✔	X	X	X

Scientific Basis for Testing Methods

One testing method for the absorbance spectrum of the tested drink is rooted in the principles of absorption spectroscopy and Beer's Law. Absorption spectroscopy is based on principles in organic chemistry where the quantum state of an atom or molecule depends on the energy of its electrons. When an incidence frequency of light is applied to a sample compound, that compound will have a specific absorbance of that particular frequency of light because of its inherent quantum state that is characteristic of its chemical structure. This relationship is quantifiably defined as Beer's Law:

$$A = \epsilon L c \quad (1)$$

where A is the sample's absorbance, ϵ is the molar absorptivity constant, L is the path length (which would be the diameter of the channel in our devices), and c would be the sample concentration. When absorbances are measured and plotted across a range of frequencies, a sample's specific absorption spectrum is elicited for a particular compound. The drugs we are testing for are particularly notable in that their structure in Figure 1 gives them a relatively high double and conjugated bonded character. The nonbonding electrons in those bonds give characteristically unique absorption spectra in the ultraviolet range that can help delineate our contaminants from other compounds. In the Product Concept section, we elaborate on how our product is designed to detect the contamination of flunitrazepam using its absorption spectrum.

The second testing method that we will employ to determine the presence of a spiked beverage is based on the inherent oxidation-reduction chemistry of most organic compounds. Because the organic compounds we would want to test for (outlined in Figure 1) all have dipole moments that create an unequal sharing of the electrons in their chemical structure, these electrons can be gained or lost (reduction/oxidation) when an electrical potential is applied in a solution. Therefore, when a spiked drink comes in contact with our electrode, an initial negative potential can be applied to the electrode and then linearly increase to a more positive potential. This will cause the organic drug to lose its electrons to a more positive potential. When current (or transfer of the electrons) is measured as a function of this increasing electrical potential, a positive peak in current will be present when the compound undergoes oxidation by losing electrons to the electrode. This process can then be reversed by lowering the potential which will cause the electrons to be gained back by the organic drug (reduction). When the drug is reduced, a negative peak in the current will be measured. By measuring the difference between the

positive oxidation peak and the negative reduction peak, the concentration of the drug can be measured. A greater concentration of the drug will have a greater peak because of the large shift in equilibrium between the oxidized and reduced forms of the drugs.

PRODUCT CONCEPT

In order to implement the spectroscopic and electrochemical testing methods, we designed a device with the assembly components needed to run both of these tests simultaneously and continuously. As mentioned earlier, we limited our research and design parameters to test for flunitrazepam (Rohypnol) for ease of design, but based on the scientific principles of our testing methods, our device could work for other drugs with additional research and development. Drink Guardian is a 3.5 cm x 3.33 cm x 3 cm silicone mold with our electrical and testing components contained inside the device. The base device would take up about 7% of the volume of a solo cup and is clipped to the side of the container in use using an adjustable 13 cm long clip. The full layout of our device is illustrated in our schematic in Figure 2, and a detailed outline of the sizing of each component of our device is outlined in Table 2. The functions of each component will be outlined in the subsequent sections of this report.

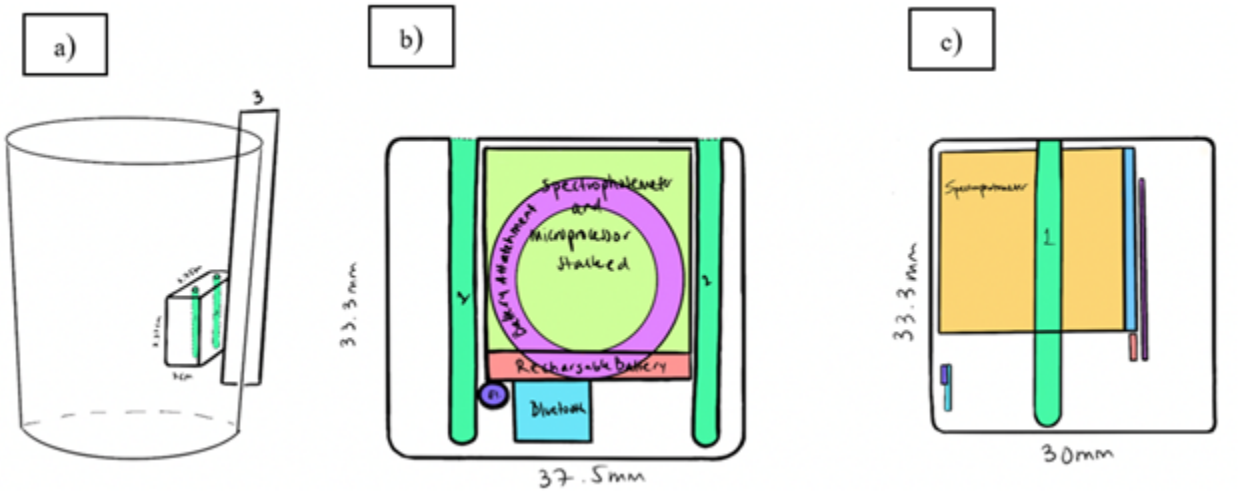

Figure 2: Drink Guardian Schematic from a: a) Macroscopic View, b) Length by Width View, and c) Width by Depth View

Table 2: Dimensions of Drink Guardian's Components

Component	Size
Silicone	~12 cm^3
Rechargeable 3V Button Battery	20 mm x 3.2 mm
Bluetooth Low Energy Attachment	0.6 cm x 0.8 cm
Microprocessor	2 cm x 2 cm
Spectrophotometer	2 cm x 2 cm x 2 cm
Electrode	3 cm x 1 cm; 2 mm
Charger	3.2 cm^2

Silicone Molding and Capillary Tubing

Silicone was chosen to make the device both sturdy and water resistant so that the interior of the device would create a relatively isolated microenvironment for testing. This molding is also used for the attached adjustable clip. This microenvironment is also created by the two capillary tubes that penetrate our silicone mold to the area where the testing actually takes place, as illustrated in green in Figure 2. It should be noted that when the device is in use, the tube's openings are present on the top side of the device to receive the drink. This tubing is washable in a typical dishwasher, and rinsing using clean water after a washing can reasonably sterilize the tubing/testing area. Adjacent to the tubing are our two testing devices, a microspectrophotometer and a screen-printed graphene electrode, illustrated in yellow and purple respectively in our schematic.

Microspectrophotometer

The microspectrophotometer would conduct the absorption spectroscopy testing described in the background section of this report for flunitrazepam by shining an incident light through its lens on one side of the capillary tube and receiving that light through a different lens on the other side of the capillary tube. After research into the literature for the particular

absorption spectrum for flunitrazepam, we found an article published in February of 2013 that obtained the absorption spectrum for flunitrazepam, which is provided in Figure 3.[3]

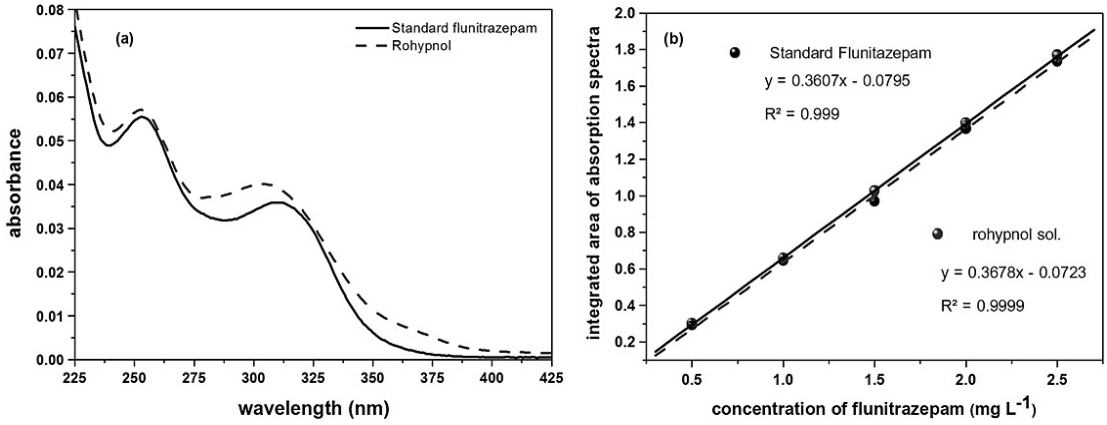

Figure 3: Absorption Spectrum For Flunitrazepam (Rohypnol) at 1 mg/L

As seen from the graph, flunitrazepam has two distinct peaks at both 255 nm and 315 nm that can help delineate the drug from other components in the drink that the microspectrophotometer would recognize. Flunitrazepam also has a protonated absorption spectrum that has an even more distinct peak at 275 nm that can be viewed in Appendix A Figure 6. These peaks were obtained from a sample of flunitrazepam at 1 mg/L in ethanol which is the standard dosage for a Rohypnol tablet, but the detection limit for the study in question was 1 ng/mL which is well below our target detection of 400 ng/mL that the microspectrophotometer needs to scan for.

After determining that flunitrazepam had a distinct enough spectrum to be detected by our spectrophotometer, we needed to elucidate whether the spectroscopy of other components in a mixed drink would overlap with flunitrazepam in our microspectrophotometer thereby causing a false positive or a false negative. Ethanol, by itself, is more than 99.5% suitable for absorption spectra analysis.[12] Most sodas in mixed drinks are primarily composed of carbonated water, phosphoric acid, and caffeine, and the only one of those compounds with a significant spectroscopic peak is caffeine at 398 nm which is very upstream of our target frequency. An absorption spectrum for Coca-Cola is presented in Appendix A, Figure 7.[13] Finally, a selection of absorption spectra for various mixers and liquors can also be found in Appendix A, Figure 8.[14] The only mixer that has significant overlap with flunitrazepam is brandy's peak at about 275 nm, however, that peak is significantly broader than flunitrazepam's peak at 255 nm and does not have an additional peak at 315 nm like flunitrazepam.

Screen Printed Graphene Electrode

Adjacent to the other capillary tube is our screen-printed graphene electrode (SPGE) where our electrochemical testing will take place. The SPGE commonly has a shelf life of about six months, but that is under continued and relatively constant use.[15] Therefore, we are confident that our electrode can last a year of somewhat regular use until it can be sent back to our team for replacement which has been included in our operating and business costs. The SPGE electrode will change potential cyclically based on its battery, where it receives its power, and the microprocessor, which will be wired into the electrode to receive its data. This cyclic raising and lowering of the potential will cause a change in oxidation state of flunitrazepam as shown in Figure 4.[4]

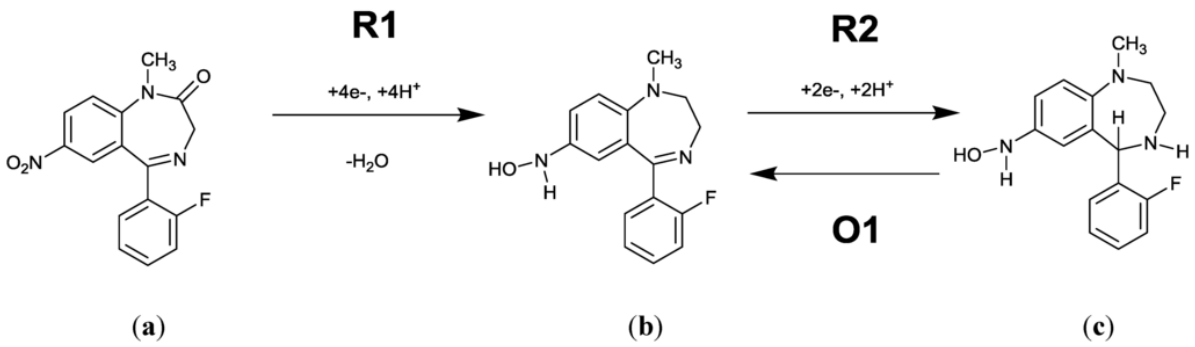

Figure 4: Oxidation-Reduction Reactions of Flunitrazepam

The oxidation-reduction reaction of importance is O1/R2 because the equilibrium in flunitrazepam changing between those oxidation states will create a positive current in O1, and a negative current in R2. This difference will be measured by the electrode to determine the concentration of flunitrazepam. An example of a voltammogram in a study depicting these peaks is shown in Figure 5, where the R2 peak is at about -0.3 V and the O1 peak is at about -0.2 V.[4]

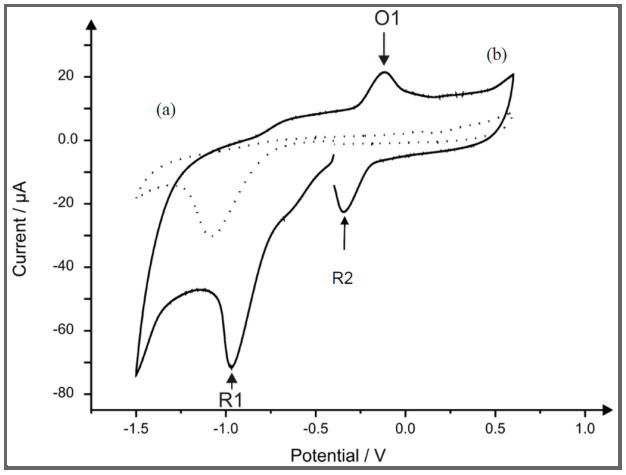

Figure 5: Voltammogram for Flunitrazepam in Ethanol Solution

These voltages and currents are important not only for tuning our SPGE, but also for safety considerations. Because we are working on the scale of microamps and millivolts, we are confident that our device has low enough power to not shock the user. However, the electronics in the device are coated in a sealant spray just to be safe. We also believe that these tests can be conducted in a more sophisticated mixed drink solution as the same study performed the experiment in a Gin and Tonic solution and accurately discerned the flunitrazepam concentration of the drink.[4] This figure can be viewed in Appendix A, Figure 9. Additionally, the detection limit for this study was 181 ng/mL which is also below our target detection of 400 ng/mL.

Data Processing and Battery

After our microspectrophotometer (pictured in blue in the attachment) reads the sample's absorption spectrum and our electrode reads the current for its cycling voltages, we need to feed this data to our microprocessor to process the data. This microprocessor will analyze the data based on machine learning techniques developed in our research and development timeline to determine whether the data corresponds to the positive signal for flunitrazepam. That verdict will then be fed to our low energy bluetooth attachment (pictured in teal in the schematic) so that it can be sent to our app. The app will then alert both the user and their designated guardian that the device has detected a foreign substance. It is important to note that the microprocessor will analyze both tests separately, and report whether either test received a positive signal in order to have robust protection against a false negative. All of the device's electrical components will be powered using a 3 V battery (pictured in red in the schematic) that has a wireless charging

attachment (pictured in purple in the schematic). Another important detail to note is that we assume a good portion of the empty space in the schematic will be taken up with electrical wiring.

MANUFACTURING PROCESS

The manufacturing process of our product will be based off of the assembly line model, wherein there will be only one working line for the assembly of our units. Figure 6 details the main steps that will be taken in order to successfully manufacture Drink Guardian.

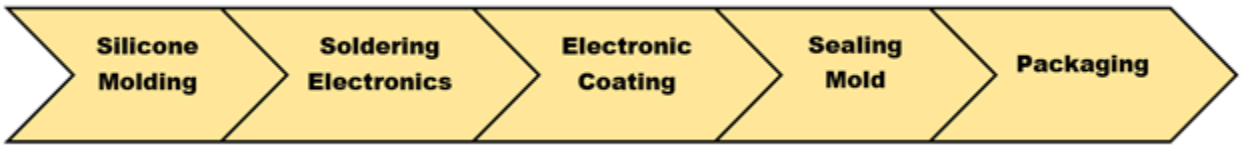

Figure 6: The steps necessary to manufacture Drink Guardian.

Silicone Molding

The first main step in the manufacturing process will be the creation of the silicone mold that will serve as the outer shell for Drink Guardian. We plan on using the Digg Desktop Injection Molding Machine to create two separate halves of the shell and the cylindrical clip handle that will attach to the cup the beverage is contained in. It is important that the shell is prepared as two separate parts during this phase as the electronic components will have to be added to the interior later on. The amount of total silicone required per unit is provided in Table 2. More specifically, however, the actual shell (i.e. both halves) will require about 13 cm^3 of silicone whereas the clip will require about 12 cm^3. Finally, given that the machine is mostly automated, it will require only 2 people to operate it.

Soldering Electronics

Following the silicone molding will be the soldering of the various electronic components required for Drink Guardian. This will be accomplished using the Weller WTBR 1000 Benchtop Soldering Robot--a robust and steady soldering machine that possesses an accuracy of 20 μm and operates at a maximum speed of 200 mm/s. It is this fast rate which allows us to construct each unit using only one assembly line given that one unit was calculated to have a total soldering

distance of about 304 mm. As such, it will take only one hour to complete soldering for about 2700 units. For this step of the process, there will be 2 people who will load the electronics onto one of the halves of the shells made in the previous step, as well as to help monitor the machine in order to ensure that the process is running smoothly.

Electrical Coating

Once the electrical components have been appropriately soldered on, they will then have 3M Scotchkote Electrical Coating applied to them. This step of the assembly process is imperative given that Drink Guardian is intended for prolonged use while submerged in a liquid. In other words, it is necessary to prevent any liquid from damaging the electronics of the product. This particular coating was chosen because it is meant to be weather resistant, and should therefore be able to handle the less extreme scenario of being placed inside a drink. This phase of the process will require only one worker because it takes about 12 minutes for the outer layer of the coating to dry.

Sealing Mold

Following the application of the electrical coating is the complete assembly of the outer shell. This final step will simply utilize J-B Weld Epoxy Adhesive in order to glue together the two halves of the silicone mold, as well as attach the cylindrical clip. By this point, one half of the mold will contain all of the coated electronics soldered onto it, whereas the other half will be empty. Once these two parts are glued together, the cylindrical clip will then be glued onto this newly assembled outer shell. In order to ensure that the parts are properly glued together, they will be left to dry for 24 hours in accordance to the specifications provided for this particular type of adhesive. Because of this, it will take about a day before the final product can be packaged. As such, 2 workers will be required to glue the parts together in order to efficiently produce a large number of completed products per day.

Packaging

Once Drink Guardian is officially assembled, it will then be packaged for shipment. Each unit will be packaged in a small 15.24 cm x 10.16 cm x 10.16 cm box to be used for individual sale or distribution. However, for shipment purposes, about 2960 Drink Guardians will be packaged in a larger 55.8 cm x 55.88 cm x 53.34 cm box. This packaging model was chosen because we currently intend to sell our product to colleges and universities, and therefore we

must choose a packaging method that is capable of supplying as many units as possible in one shipment.

ECONOMIC ANALYSIS

We conducted a financial analysis on Drink Guardian to determine how viable it is to manufacture and sell. In this section, we explore the market and revenue that we could generate, and the costs associated with producing the product. All of these metrics are summarized in the NPV graph at the end of this section.

Market and Revenue

We based our expected sales on the amount of freshmen that party per year. There are about 20 million college students in Fall 2020, and we take a quarter of those people to be freshmen.[16] According to a UCLA study, about 53% of freshmen do some partying at college.[17] If we assume Drink Guardian would capture 10% of the market, we can then assume that we would sell 293,500 devices in our first year on market. This corresponds to around 300 universities in the US buying enough devices for their entire freshman class. If we price our device at $100, we expect an initial annual revenue of $25 million. We expect that the number of devices sold and thus our revenue would increase by 20% annually to reflect new universities buying our product along with the universities already buying our devices yearly. We also expect our sales to plateau after 50% of all universities are buying our product, or after 11 years. See Appendix C, Table 3 for more details.

Development Costs

We estimate our development will take two years. During this time, we will hire 12 scientists, engineers, and software developers to prototype our product. We will have two software developers develop the app that will interface with our device. We then need three people to build the device, three people to test the device, and four people to determine the logistics of mass-producing this device. We assumed that the average salary of all our workers is the same as the average salary for a chemical engineer. We will also need lab space, testing equipment, chemicals, and building materials to develop our product. See Appendix C Table 4 for more details.

Capital Costs

Based on our initial estimates, we need to produce 1132 devices per day. This number can be easily met with an automated injection molding machine, soldering machine, and people manually spraying sealant and inspecting the devices. We will also need a workspace, tools, a storage facility, and extraneous materials to develop our facility. Our warehouse will be roughly 10,080 square feet in space. The building of the facility will take a year. We assume a Lang Factor for installation and maintenance of 3.1 to account for the fact that we are mainly a solids assembly plant. See Appendix C, Table 5 for more details.

Operating Costs

Our operating costs comprise our raw materials, costs of running the plant, and the workers necessary for the plant. Our raw materials amounted to roughly $40.57. See Appendix C, Table 6 for more details. As mentioned earlier in the manufacturing process section, we assume that we have nine workers in the plant. Our administrative and maintenance costs account for people to inspect the devices and the management of the workers. We assume our total operating costs increase by 5% every year. See Appendix C, Table 7 for more details.

Business Costs

Our business costs come from the cost of marketing, support of our product, and legal fees. We set a large portion of our business costs for marketing to hundreds of universities and another portion to the inevitable legal fees that will arise out of the use of our product and possible defects. These business costs also include the warranty of the device. These costs should start being accrued in year 4. See Appendix C, Table 8 for more details.

Cash Flow and Net Present Value

The sum of our revenue and cost streams yields Drink Guardian's cash flow. The first two years consists of development costs, and year 3 is the capital cost. We assume a 35% tax, a 20% increase in revenue annually, and a 5% increase in operating costs annually. Interest is compounded annually at 10%. We believe that our revenue will asymptote at roughly 11 years, which is when 50% of our target market is captured. Thus, we only model our NPV table in Appendix C, Table 9 and NPV graph in Figure 7 until year 10. We hope to break even with our investment in about 5 years.

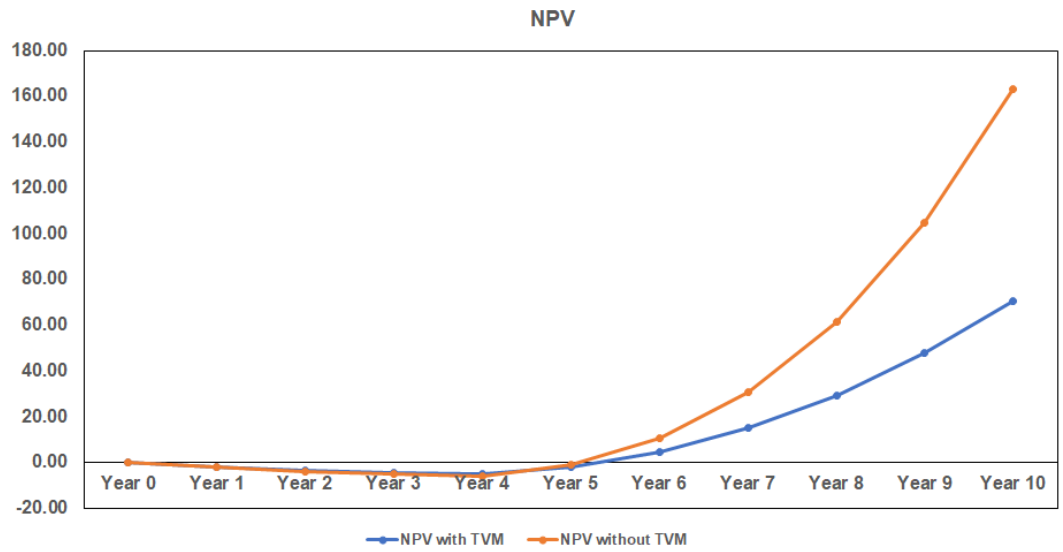

Figure 7: A graph of our Net Present Value. Note that the payback period is about 5 years.

DISCUSSION

Here we discuss how viable the product is as a concept. Drink Guardian should not encounter any issues with copyright due to our innovations. Our device should also not pose a health risk to its users due to our careful design.

Intellectual Property

Drink Guardian differs from other sedative detectors because of its two-factor authentication, reusability, constant monitoring, and communication with a sober partner. Of the few patents filed for various products, none of them include a bluetooth connection with a neighboring mobile device. In fact, none of these devices with patents have any electronic capabilities. Therefore, Drink Guardian would not encounter any copyright issues with other sedative detectors. We may have to license some of the components used in the device such as the spectrophotometer.

Safety Considerations and Regulations

Our device should not have any issues with contamination of drinks. Our mold is made of silicone, a material that is non-toxic and is used in different cooking utensils.[18] We seal all of the electrical components with a silicone spray and leave a wide margin of space between the electrical components and the outside environment, ensuring that no electricity flows from the

device into the drink. As a second safeguard, we also ensure that the electricity usage of the device is negligible compared to the amount of electricity necessary to cause harm. The main power usage of our device comes from the bluetooth which runs at about 0.1 μA. This is much smaller than the amount of current it takes for a human to perceive a shock.[19] Our device is not a medical device as it does not diagnose any diseases or conditions, nor does it affect the structure or function of a human. Therefore, we will not require any FDA approval for our device.

CONCLUSION

In conclusion, the current climate surrounding college house parties is dangerous, and current products on market fail to address this issue. The current market for products aimed to detect spiked drinks is small with no product being able to perform continuous, multiple tests for verification. This is where Drink Guardian comes in. Drink Guardian is able to constantly monitor drinks with a robust testing system that also alerts the user, and a sober partner of their choice, if a drug is detected. We believe that our reusable Drink Guardian will be profitable, while revolutionizing safety across college campuses.

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APPENDIX

Appendix A: Background Data for Spectroscopic Testing

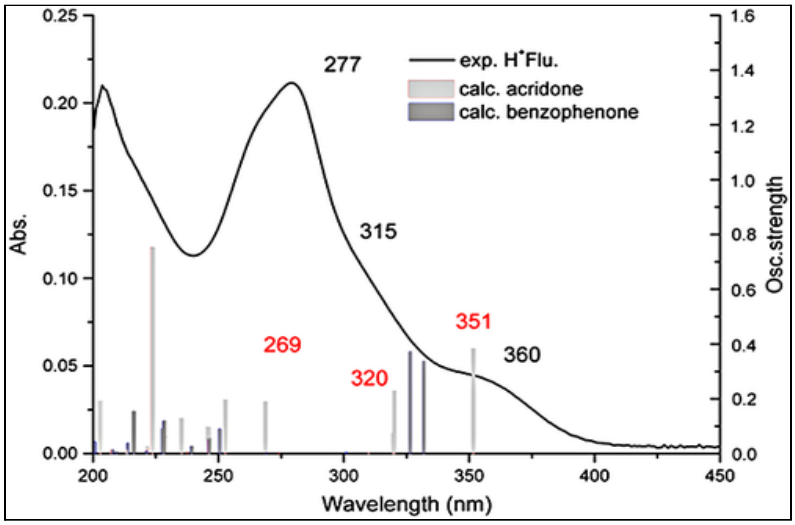

Figure 8: Absorption Spectrum of Protonated Flunitrazepam (Rohypnol)

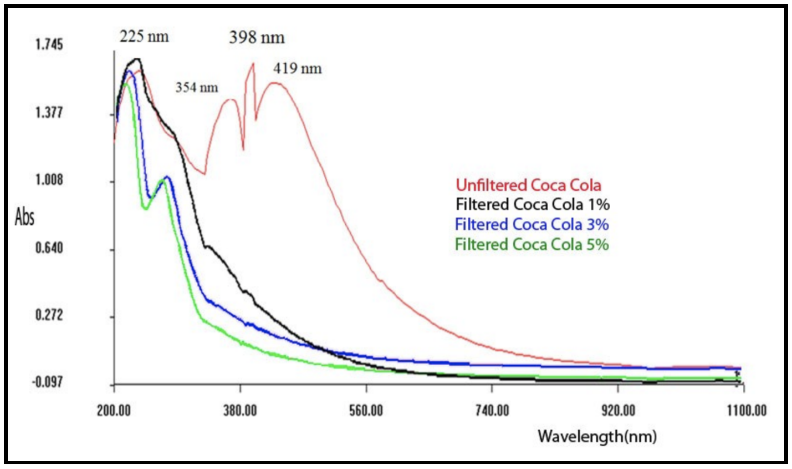

Figure 9: Absorption Spectra for Coca-Cola

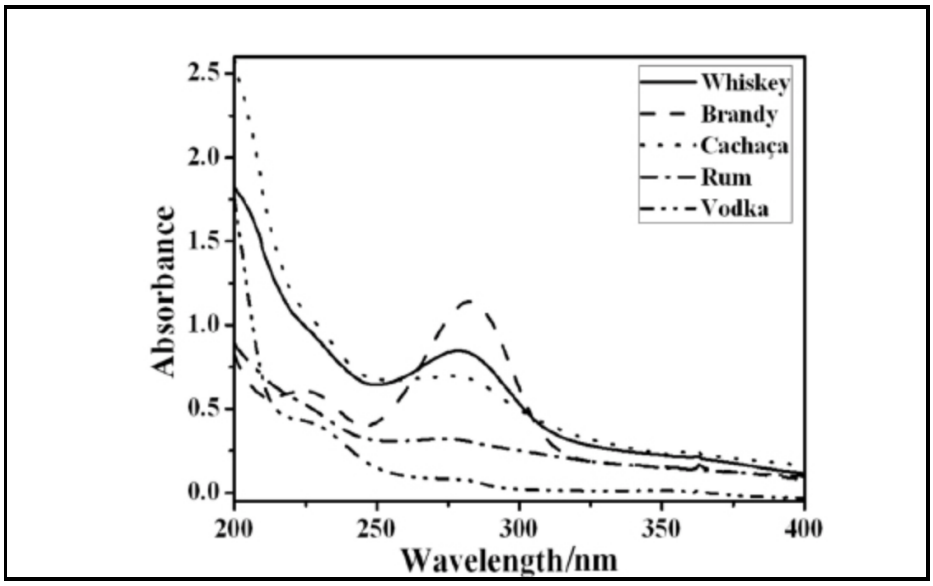

Figure 10: Absorption Spectra for Various Liquors and mixers

Appendix B: Background Data for Electrochemical Testing

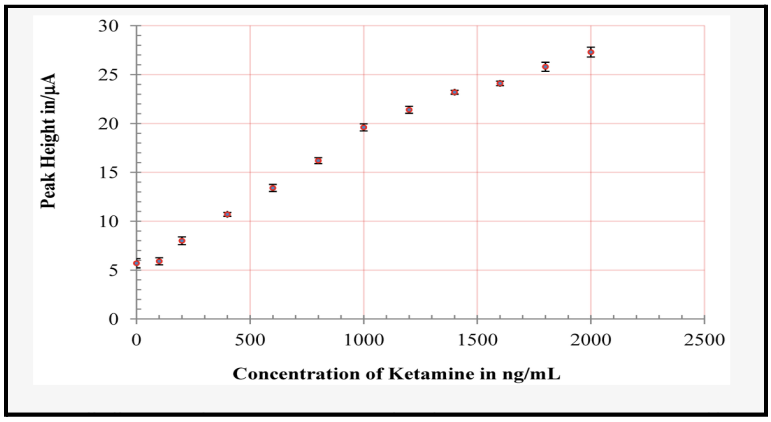

Figure 11: Determination of Flunitrazepam Concentration in Gin and Tonic Solution using Electrochemical Testing

Appendix C: Supplementary Financials for Drink Guardian

Table 3: An overview of the Initial Annual Revenue of Our Product

Total Units Per Year	293,500
Price per Unit	$100
Product to Market Fee	0.85
Initial Estimated Total Revenue Per Year	$25,000,000

Table 4: An Estimate of Our Annual Development Costs

Development Cost	
People	12
Salary	$108,770
Benefits	$32,631.0
Lab + Testing Equipment	$300,000
Chemicals + Building Materials	$50,000
Development Time (Years)	1
Total	$2,000,000

Table 5: Our estimated annual capital costs, which will be accrued for one year

Units	Unit Cost	Number of Units	Total Cost
Soldering Machine	$41,043.54	1	$41,043.54
Injection machine	$50,000.00	1	$50,000.00
Workspace	$75,600.00	1	$75,600.00
Storage(Crates)	$39.09	926.6261194	$36,221.82
Tools	$10,000.00	1	$10,000.00
Total Battery Site Cost	$212,865.36		
Off-sites	$21,286.54		
Lang Factor (3.1)	$659,882.60		
Contingency	$63,859.61		
Engineering Management	$42,573.07		
Total Capital Cost	$1,000,467.17		

Table 6: Our estimated raw materials cost for every Drink Guardian device

Equipment/Materials	Prices	Price per Device
Silicone Build	$19/lb	$2.51
Spectrophotometer	$10/device	$10.00
Electrode	$5.83/Device	$5.83
Battery	$1.3998/device	$1.40
Microprocessor	$5/device	$5.00
Bluetooth Attachment	$7/device	$7.00
Electrical Coating	$28/15 oz.	$1.87
Wireless Charging Attachment	$5.90/device	$5.90
Wiring+Adapter	$1/device	$1.00
Metal Glue	$5.68/2oz	$2.84
Total	$43.35	

Table 7: An Overview of Our Annual Operating Costs

Cost of Raw Materials per year	$12,722,855.50
Cost of Labor	$363,000
Supplies	$108,900.0
Non operational labor	$181,500.0
Administrative	$326,700.0
Benefits	$108,900.0
Maintenance	$30,014.02
Insurance and Energy	$15,007.01
Depreciation	$100,046.72
Packaging(Small Boxes)	$2,298,105.00
Packaging(Large Boxes)	$4,559.00
Total Operating Costs/Yr	$16,259,587

Table 8: The Annual Business Cost of Running Our Plant

Business Cost	
Sales and Marketing	$3,000,000
Distribution Costs	$1,400,000
Ongoing research support	$100,000
Technical Support	$3,000,000
Improvements with Time	$100,000
Legal Fees/Settlement Costs	$1,000,000
Salary/(Person*Year)	$543,850
Benefits	$163,155.0
Chemicals + Building Materials	$1,000
Estimated Total Annual Business Costs	$9,300,000

Table 9: An overview of the overall cash flow of Drink Guardian

Type of Cost (in millions of dollars)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Revenue	0.00	0.00	0.00	24.95	29.94	35.92	43.11	51.73	62.08	74.49
Development	2.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Capital	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operating	0.00	0.00	0.00	16.26	17.07	17.93	18.82	19.76	20.75	21.79
Business	0.00	0.00	0.00	9.30	9.30	9.30	9.30	9.30	9.30	9.30
Gross Profit	-2.00	-2.00	-1.00	-0.61	3.57	8.70	14.99	22.67	32.03	43.40
Taxes	0.00	0.00	0.00	-0.21	1.25	3.04	5.25	7.93	11.21	15.19
Net Income	-2.00	-2.00	-1.00	-0.83	4.81	11.74	20.23	30.60	43.24	58.60
Discount Factor	1.10	1.21	1.33	1.46	1.61	1.77	1.95	2.14	2.36	2.59
Discounted Cash Flow	-1.82	-1.65	-0.75	-0.56	2.99	6.63	10.38	14.27	18.34	22.59
NPV (TVM)	-1.82	-3.47	-4.22	-4.78	-1.79	4.83	15.22	29.49	47.82	70.41
NPV (NO TVM)	-2.00	-3.99	-4.99	-5.82	-1.01	10.74	30.97	61.57	104.81	163.40