Automating Prostate Cancer Diagnosis to Improve Healthcare Efficiency

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Introduction

Abstract

Billions of dollars are wasted in healthcare every year. It is without a doubt that in the US, healthcare is incredibly inefficient, costing a lot of money for the average American and not getting people the proper care. Part of the reason for this is the lack of standardization. Protocols for specialty treatments are constantly changing and it is impossible for general practitioners to keep up. This causes outdated treatments for patients and often unnecessary procedures. I believe that with the use of automation and software, we can begin to solve this problem.

I will start with attempting to automate prostate cancer screening and move onto other protocols afterwards. The American Urology Association (AUA) has published guidelines that turn into a decision tree for moving patients along the screening process. I will code up a platform that will allow doctors to input their patients info and then automatically provide recommendations on next steps based on the AUA guidelines. I will also design a data analytics dashboard to track how patients are moving through the protocol and record important information such as spending and performance. Finally, I will compare these KPIs with similar metrics of how doctors are currently approaching prostate cancer screening to see if we see any significant improvements.

Context

In order to understand this project fully, one needs to understand the healthcare spending inefficiencies in the USA. As mentioned previously, billions of dollars are wasted in healthcare every year. Amongst all modern countries, the US spends more than any other country per citizen on healthcare. There are three main reasons for this: **(1) administrative issues and wasted time spent with doctors and nurses, (2) doctors following outdated protocols - there is a lack of standardization for doctors, and protocols for specialty treatments are constantly changing, making it hard to keep up, and (3) unnecessary procedures.** Essentially, doctors are spending too much time with patients, only to give them outdated information, or send patients to a specialist doctor who will perform an expensive procedure in order to get paid.

That being said, recently, there has been an increased interest in cost effective healthcare, partly due to the rise in ACOs or Value Based Care Organizations. ACOs are a conglomerate of health groups (e.g. hospitals, general practitioners) that partner with insurance companies to provide the best care. Insurance companies designate a budget for the ACO, and every dollar not spent below that budget gets split between the insurance company and the ACO (e.g. the insurance company designates $200 million to an ACO, if the ACO only spends $150 million, then there is $50 million leftover for the insurance company and the ACO to keep), thus promoting cost effective healthcare. For the first time in the US, doctors are incentivized to give the best healthcare to patients at the lowest cost. Currently, ACOs are solely for medicare and medicaid patients with

every medicare/medicaid patient expected to participate by 2030. Although only medicare/medicaid patients are the direct beneficiaries, around 50% of physicians are currently members of ACOs, so, as this model grows, it is increasingly important to find solutions to reduce unnecessary costs.

One area that particularly struggles with the inefficient spending challenges mentioned above is prostate cancer diagnosis. Currently, patients take a PSA at their yearly check in, and, depending on their doctor, will get very different recommendations for next steps. After talking with multiple doctors, even the most basic details such as what classifies as a "high PSA score" varies greatly. This often leads to either poor follow up for concerning scores or referrals to a Urologist and a following prostate biopsy - a $2,000 procedure that is unnecessary 75% of the time and has a high false negative rate. Many other specialty procedures face similar problems; however, for this project, we chose to focus on prostate cancer diagnosis since it was much less severe compared to procedures such as lung cancer or cardiology.

Objective

The goal of this project is to automate and implement modern protocols for prostate cancer diagnosis. We aim to increase efficiency of this process by eliminating wasted doctor visits, providing active recommendations, referring intermediary biomarkers, democratizing medical information, and reducing costs.

The primary objective is to facilitate cost effective and improved quality prostate cancer screening through software and automation. Part of this project, however, was also to identify the efficacy of these intermediary biomarkers - blood/urine tests - in reducing the amount of unnecessary biopsies. Due to the complexity of this task and requirement of tracking large data over years, we narrowed this scope down to focusing on projections instead. Using data from the CDC and NIH, we created an expected value cost breakdown for a patient using our system vs the incumbent.

Why it's Important

Beyond the obvious answer of reducing costs, this project is important because it can democratize healthcare and potentially save lives. After performing many customer discovery calls and meeting with patients and doctors alike, it is very clear that a solution such as this would result in better treatment for patients. Specifically for prostate cancer screening, one customer I interviewed mentioned not being monitored correctly after a concerning PSA score, only to ultimately find out he had severe prostate cancer at his next annual check in. If this system was in place, he would have followed the up-to-date, modern guidelines, and been able to slow the progression of his cancer.

Extending beyond prostate cancer, this has applications in other specialty processes as well. For instance, lung cancer, cardiology, neurology, etc. would all benefit from a similar platform. These paths have much larger complexities - leaving room for more subjectivity - and have incredibly high costs. Lowering the costs for these patients would help them drastically. Very often in the states one would hear people avoiding getting a procedure or doctor appointment due to the costs. Therefore, with reduced costs, perhaps a patient can now afford to get a life saving procedure.

Additionally, one element I wish to grow for this platform is the educational aspect. We could upload new information on protocols and provide articles and foreshadowing to patients as they go through a diagnosis process. This could cause comfort and allow these patients to make the most educated decisions for their health. We could also expand this beyond just the states. Later in the report, it is noted that during our beta test in Mexico, we encountered the challenge of individuals not undergoing regular prostate cancer screenings due to insufficient awareness. As this platform grows, we can democratize healthcare by providing everyone with the best information on their healthcare journey, regardless of their geographic location. This also allows us to gather data and showcase which methodologies/medicines/tests are truly the best rather than blindly trusting the few big pharmaceutical companies that charge high premiums for their medicine.

Questions We Aim to Answer

Throughout our project, we had a few key questions in mind to further understand the problem and to determine whether we would be successful. Although we were not able to answer all of these, I still believe they should be evaluated at a future point. The questions are listed below:

- Can we automate prostate cancer screening?
- Will doctors adopt this new technology?
- Will following guidelines reduce wasteful procedures and spending?
- What will data analytics show using proper protocols vs current methodologies?
- Is there a viable business by providing this service to general practitioners?
- Will automated procedures prohibit outlier patients from getting proper treatment?
- What do current healthcare systems look like for assisting day-to-day practices of doctors?
- Do biomarkers prevent unnecessary biopsies without sacrificing accuracy on people who have cancer?
- Are biomarkers more cost effective than biopsies?

Methodology

Data Analytics

Before diving into actually developing the product, we had to perform cost benefit analysis on implementing the new AUA guidelines over current methodologies. If we discovered that current methodologies proved to be cheaper than the new algorithm we wanted to automate on our platform, then we would no longer have a product and would be forced to pivot in a new direction. This task proved to be quite difficult and required extensive research using theoretical numbers from the NIH and CDC.

We began by gathering data on the cost for each step along the process and finding the likelihood for a patient to continue moving forward onto the next steps based on their scores. Some data that we collected included, cost for general practitioner visit, cost of a Urologist visit, average number of Urologist visits needed, cost of a biopsy, cost of an MRI, cost of sepsis, what's the percent of men that get a high PSA score, what's the percent of men that need a prostate biopsy, and more.

We then separated patients into 4 categories and performed our expected value calculations. For starters, we looked at the expected value of a patient that has prostate cancer and will need a biopsy for both methods. In the current methodology, we found the expected value for the entire process to be around $3,690. This calculation is shown in the figure below. When looking at the expected value with the new AUA guidelines we found the expected value of patients who have prostate cancer to be around $3,790. Although it is slightly more expensive, this is entirely reasonable since one of the main changes from the new AUA guidelines includes introducing an intermediary biomarker test - a blood or urine test taken before a biopsy - which can cost around $200. Therefore, the patient is inducing a slightly increased cost if they have prostate cancer. That being said, there are also slight decreases in the number of visits, so it is not a flat $200 increase in expected value.

Market Sizing with Customizable Variables and Adding 4k to Old Protocol Process At Biopsy						Chance of Eact
	Cost of Initial GP Visit	100	https://kheal			100.0%
	Cost of Additional GP Visit	100	https://kheal			100.0%
	Cost of Urologist	890	356	Per visit, average visits input to the right	2.5	100.0%
	Cost of 4k		INPUT			100%
	Cost of Biopsy	2000	https://www.			100.0%
	Cost of Sepsis	2300	https://suo-al			5.0%
	Cost of Hospitalization	13000	https://www.			1.8%
	Cost of MRI	500	https://news.			50.0%
					Percent MRI	0.0%
Expected Value of Patient Getting a Biopsy	3689	**Expected Value of Patient From After Elevated PSA**	1,616		**Expected Value of Patient From Urology Referral**	1,416

Figure 1: This shows different expected value calculations for patients who have prostate cancer and follow current methodologies. The "4k score" is an example of an intermediary biomarker the AUA wants to begin including, and currently it is not used so there is no cost associated.

The next two categories of patients; however, include finding the expected value for patients that don't have prostate cancer. This is where large savings are supposed to occur because these intermediary biomarkers claim to reduce unnecessary biopsies by up to 40%. When performing these calculations, I felt it was important to keep the cost of these biomarkers as a variable, as well as the percentage of biopsies reduced. This was done due to limited data on these biomarkers and to showcase worst, base, and best case scenarios. As seen below, there is a goldilocks zone that produces around $200 in savings on average per patient and, since most patients don't have prostate cancer, overall the new AUA guidelines should theoretically provide some savings.

Savings Table For ACOs Per Patient Reflexing All Elevated PSAs

		Cost of Biomarker												
		100	150	200	250	300	350	400	450	500	550	600	650	700
Percent Decrease in Biopsy	0.05	196	146	96	46	(4)	(54)	(104)	(154)	(204)	(254)	(304)	(354)	(404)
	0.1	213	163	113	63	13	(37)	(87)	(137)	(187)	(237)	(287)	(337)	(387)
	0.15	231	181	131	81	31	(19)	(69)	(119)	(169)	(219)	(269)	(319)	(369)
	0.2	248	198	148	98	48	(2)	(52)	(102)	(152)	(202)	(252)	(302)	(352)
	0.25	266	216	166	116	66	16	(34)	(84)	(134)	(184)	(234)	(284)	(334)
	0.3	284	234	184	134	84	34	(16)	(66)	(116)	(166)	(216)	(266)	(316)
	0.35	301	251	201	151	101	51	1	(49)	(99)	(149)	(199)	(249)	(299)
	0.4	319	269	219	169	119	69	19	(31)	(81)	(131)	(181)	(231)	(281)
	0.45	337	287	237	187	137	87	37	(13)	(63)	(113)	(163)	(213)	(263)
	0.5	354	304	254	204	154	104	54	4	(46)	(96)	(146)	(196)	(246)
	0.55	372	322	272	222	172	122	72	22	(28)	(78)	(128)	(178)	(228)
	0.6	389	339	289	239	189	139	89	39	(11)	(61)	(111)	(161)	(211)
	0.65	407	357	307	257	207	157	107	57	7	(43)	(93)	(143)	(193)
	0.7	425	375	325	275	225	175	125	75	25	(25)	(75)	(125)	(175)
	0.75	442	392	342	292	242	192	142	92	42	(8)	(58)	(108)	(158)
	0.8	460	410	360	310	260	210	160	110	60	10	(40)	(90)	(140)
	0.85	477	427	377	327	277	227	177	127	77	27	(23)	(73)	(123)
	0.9	495	445	395	345	295	245	195	145	95	45	(5)	(55)	(105)
	0.95	513	463	413	363	313	263	213	163	113	63	13	(37)	(87)
	1	530	480	430	380	330	280	230	180	130	80	30	(20)	(70)

Figure 2: This showcases the chart for the difference in expected value of the new AUA guidelines and the old methodology for prostate cancer diagnosis based on the cost of the intermediary biomarkers and the percent decrease in number of biopsies they induce.

Something I find interesting about this is, once we implement our software in a practice, we can actually test these numbers out and gain data into what is accurate. Unfortunately, we were unable to launch in a US clinical office in time for the end of the semester, but this is something

that we plan to do in the future. We have also built a data analytics dashboard to track savings over time as well compared to expected values.

Protocols

As mentioned above, there are various protocols that are currently being used and it can be quite difficult to understand. We developed a pipeline to showcase the changes from old methodologies to incorporating our system and the AUA guidelines. Below are the two various processes. It was important to get this pipeline shown in order to convince doctors and physicians that our product makes things easier for the patient and saves them money.

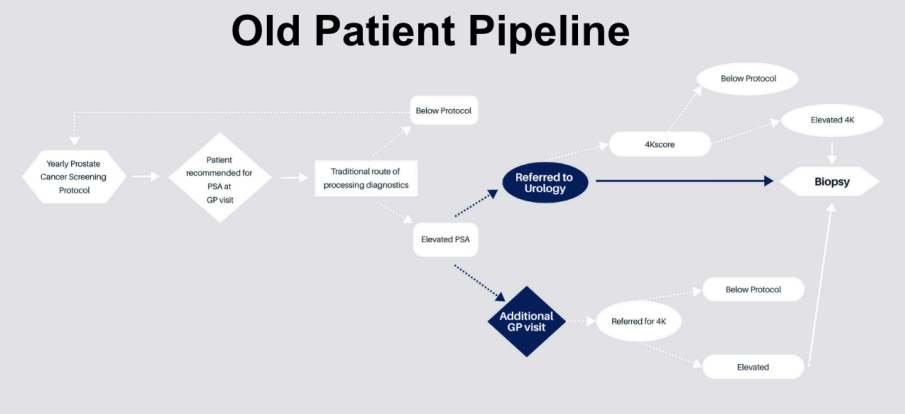


Figure 3: This shows the old methodology patients go through for prostate cancer screening. Ultimately, it is a bit clunky with some unnecessary steps.

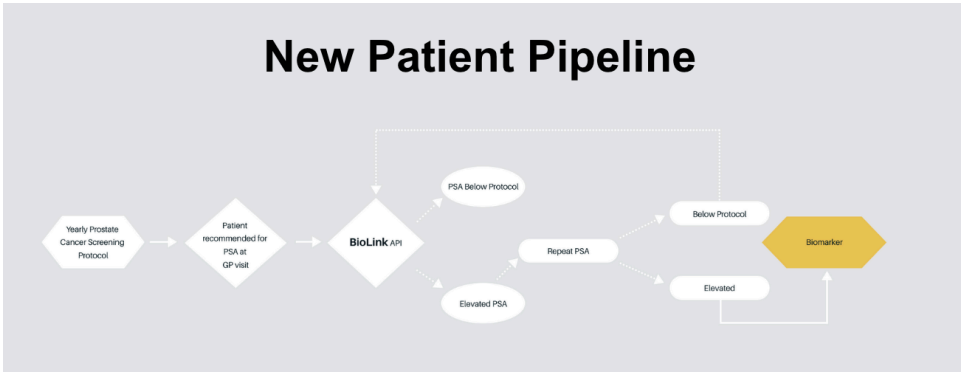


Figure 4: This shows the new process with our company, BioLink, being incorporated to make things more efficient. We reduce a lot of uncertainty and have a much more formulaic process for the patient flow.

Technical Solution and Components

After determining our product is viable from constant interaction with doctors and patients alike and performing the data analytics calculations above, we began building out a solution. Our solution is a software platform with both a physician and patient facing dashboard. In this

platform, we included relevant health and demographic information on each patient in regards to prostate cancer screening. Ultimately, to resolve the prior inefficiencies, we built an all-in-one solution for prostate cancer diagnosis which reduces wasted doctor visits and incorporates modern protocols - which in turn reduces unnecessary biopsies. The main functionality includes: (1) algorithmic recommendations for next steps, (2) patient tracking and analytics dashboard, and (3) the incorporation of intermediary biomarkers.

We implemented the protocol from the American Urology Association (AUA) guidelines that turn into a decision tree for moving patients along the screening process. We coded up a platform that allows doctors to input their patients info and then automatically receive recommendations on next steps based on the AUA guidelines. We also designed a data analytics dashboard to track how patients are moving through the protocol and record important information such as spending and performance. A few examples of these screens are shown below. In the future, we will compare these KPIs with similar metrics of how doctors are currently approaching prostate cancer screening to see if we made any significant improvements.

Our tech stack contains (1) AWS Amplify to manage different user pools, API calls, authentication, and send reminders, (2) Python for the data analytics dashboard and to implement the AUA guidelines, (3) React for front end components, and (4) a graphSQL database. Some additional features we included are: (1) an education page for more information with links attached, (2) scheduling, (3) communication, (4) doctor verification, and (5) warnings for failing to follow the procedure.

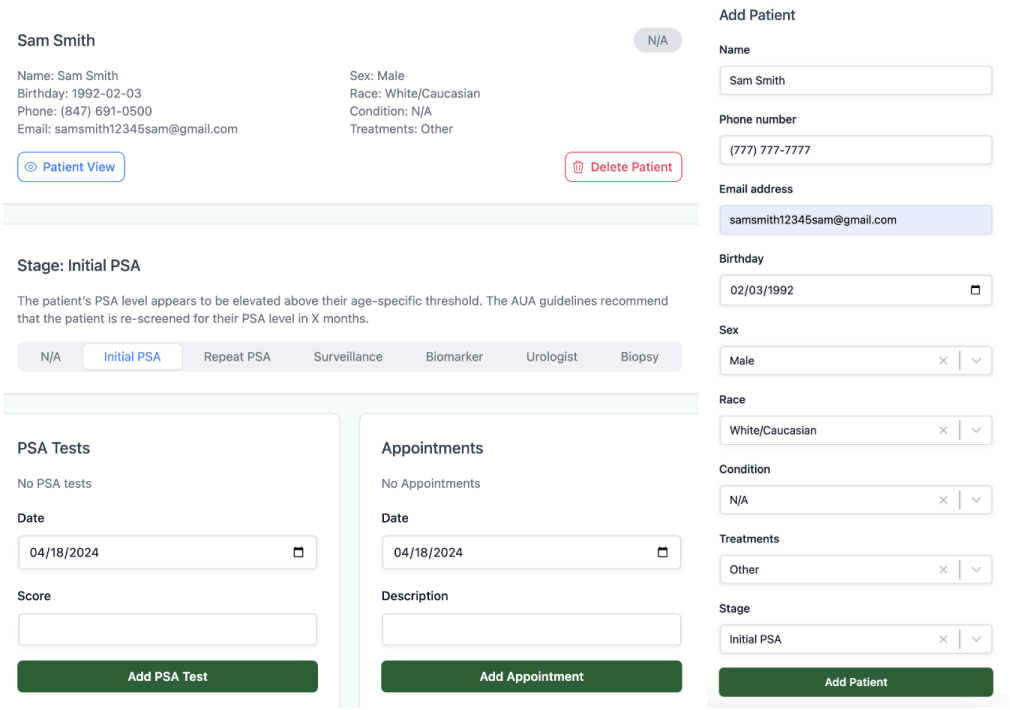


Figure 5: On the left is the physician view of a specific patient. Here the doctor can see what stage the patient is in regards to the screening process, what upcoming appointments they have, their current test results, and other basic medical information. On the right is the screen for adding a new patient. The doctor can onboard a new patient to the platform quickly and automatically receive next steps.

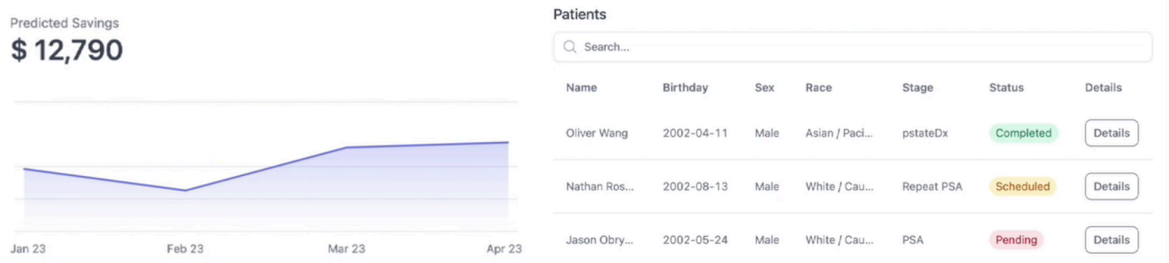


Figure 6: On the left is a basic analytics dashboard component where we show the projected savings for a physician's office while using the new protocols. This is incredibly important from a business perspective and many other efficiency components will also be included. On the right is the patient overview dashboard. It shows basic patient info to the doctor, but also highlights the status of each patient. This allows them to identify patients that are not following the proper protocol or are in critical condition much quicker.

Business Model

Another important aspect of this project involved creating a business model. Although not technically complex, for an entrepreneurial project, this step is crucial. If there is no clear plan for distribution and revenue generation, then the product has failed as a business. Our business model is rather complex, but I believe provides a great solution for everyone involved. It involved three main components: 1) targeting specifically ACO groups, 2) taking a percent of savings we induce from these ACOs, and 3) receiving sales commissions for each biomarker we sell.

For starters, ACOs are our clear target customer and are perfect for encouraging distribution. ACOs rely on cost savings and will undoubtedly attempt to use our platform if we can showcase large savings in return. Not only this, but each ACO can have thousands of physicians under their jurisdiction, so they can help push our platform out to a large audience quite quickly. Additionally, ACOs have historical metrics on how much they spend on prostate cancer annually. With our software, if we lower their costs year over year, we hope to get a percent of the savings we induce. For instance, if they typically spend $2 million on prostate cancer diagnosis each year and we reduce it to $1.7 million, then we hope to get a portion of the $300k we saved. This is a win-win since we only get paid if they save money. Another potential form of revenue comes from biomarkers. Since we are promoting intermediary biomarkers on our platform, we aim to get a percent of revenue we generate from each additional sale. These tests have an incredibly low utilization rate, so labs should be happy to agree to this partnership. Each test costs around

$100 - $300 and we hope to take around 20%. Once again, this provides a win-win as we generate revenue for these labs that they normally would not have without our platform.

Results

Failures

After intensive development, we learned the healthcare industry is incredibly difficult to enter. We hoped to continuously iterate on our product based on customer feedback, but faced many logistical challenges in our ability to launch. Some of these included: (1) HIPAA and patient data concerns, (2) the necessity for legal expertise, and (3) data acquisition. These first two issues require funding and scrutiny by external organizations, and a failure to do them could result in huge legal issues for the future. Outside of the technical and business issues, it is also hard to acquire users. Doctors are busy and typically older people, so they are unwilling to adopt a new platform unless the value is clearly outlined.

Another failure of the project came from customer retention. While we performed supervised beta tests, customers were regularly engaged and reminded to use our software, but there is a concern for patients who don't have that constant support. Attempting to gain users that were not regularly monitored would result in one time sign ups.

Successes

Overall, we did accomplish quite a bit. Not only did we build an extensive platform in such a short time, but we navigated a new entrepreneurial endeavor and overcame some of the obstacles above. I am fairly proud of the technical platform that was built. Many different techniques and technologies were combined into one with very little errors. There was limited time latency on our platform and customer feedback was overall quite positive, with only minor recommendations given. In terms of navigating a venture, I learned many various skills in leadership, management, and outreach. This product requires a team of dedicated individuals and expertise in the healthcare industry that I do not have. Additionally, throughout the course of this project, we got connected to the head of the PCEC, CMOs of different ACOs, the leaders of different prostate biomarkers, and much more.

Beyond the connections and technical skills gained, we were also successful in completing a beta test in Mexico due to less regulations and saw an increase in patients getting prostate checks with our platform. This was our first instance of patients using our platform and, partly due to supervision, we had a fairly high retention rate and saw a huge difference between patients that used the platform and those that did not. Additionally, we participated in a small screening event with PCEC to onboard and get users accustomed to our platform. This resulted in around 50 user sign ons and we will be participating in further screening events in the future. Not only this, but from the screening events, other potential opportunities with different health groups and biomarker companies have begun.

Future Work

As we met with many individuals in the healthcare industry about our project, we were told to focus next on the cognitive impairment space. Therefore, while we are working on the logistical components of launching our platform in the states, we have begun building a prototype for a cognitive impairment assessment that aims to detect variation in cognitive ability at a higher frequency and larger sensitivity than current market competitors. Some current validated tests include having patients draw a given time on a clock. Unfortunately, these tests are administered seldomly and if a patient is unable to complete this task, their cognitive function has already drastically declined. So, we have created an online assessment tool that combines what is being done in clinical offices currently and tests various cognitive abilities. Some of these assessments are shown below.

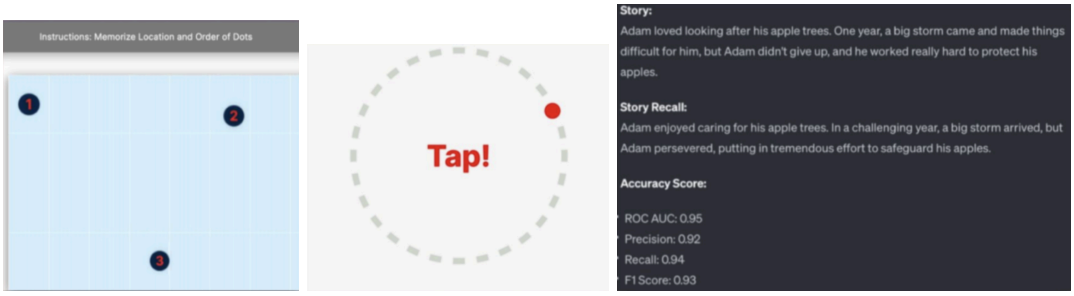


Figure X: Going from left to right, we built 1) a memorization game where users try to recall the location of dots on a grid, 2) a motor assessment to track reaction time, and 3) an AI generated story game to view a patient's short term and long term memory.

If you wish to sign up for our waitlist, fill out this form here.

Conclusion

Through thorough research, we discovered a huge problem in the healthcare industry's lack of modern technology. Not only does the US have one of the worst costs per patient out of any other country, but the quality of care varies greatly with each physician. Much of our medical practices are outdated with doctors following old protocols and not using new tests that can lower costs for their patients. This was incredibly prevalent in our work with prostate cancer diagnosis, and we found that an all encompassing software platform with modern algorithms and intermediary biomarkers implemented is a viable solution. While it is difficult to gain customer adoption, we believe that a platform with multiple protocols would see large success.

In the future, we hope to do exactly that by expanding beyond prostate cancer into other diagnosis processes such as lung cancer and cardiology. In the meantime, however, we need to resolve the data acquisition issue of getting patient information on our platform. Our current

workaround solution includes manual entry and doctor verification, but we are exploring potential integration with labs, cascade coding, web scraping EMRs, and joining FHIR servers. Additionally, in the near future, we have begun talks about a pilot launch in the states with eight clinics and a revenue sharing contract with another healthcare company. While we are still early, this project has been incredibly rewarding in culminating all of my technical skills from the past couple of years into a meaningful mission and has drastic potential to make a huge impact in healthcare. I have learned valuable skills, such as combining backend and frontend programming into one to create a usable platform, the importance of customer feedback and the entrepreneurial problem discovery journey, how to lead a team and get people excited about my vision, and constantly adapting and learning new technologies outside of what I learned in the classroom.