The Chinese University of Hong Kong

ELTU2014BC English for Engineering Students I

Assessment Task 3: Proposal

InfraStrjoke: stroke is never a joke

Group 1

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Table of Contents

(See *Work Allocation*)

0 Executive Summary

Stroke is found to be proliferating in Hong Kong. It has not only been a severe issue among the elderly group in Hong Kong, which is troubled by the exacerbated ageing problem, but it has also become a universal problem among adolescents in recent years. The increasing prevalence of stroke affects the patients' health and hinders the development of society as a whole.

Under the symptoms of stroke, the patient has an altered state of mind, severely hindering any attempts at seeking help. To much tragedy, more than 70% of stroke patients only arrive at the hospital after their golden hour of stroke is lost, resulting in permanent brain damage.

We have invented *InfraStrjoke*, a smart headband capable of detecting strokes and alerting emergency services, to tackle two of the three identified stroke aid challenges: stroke detection and post-stroke help-seeking. The core technology in *InfraStrjoke* is its near infra-red spectroscopy (NIRS) system, which can also provide other data, such as blood oxygenation and blood sugar, in addition to the mentioned stroke detection. This approach has also opened the door for the possibility of numerous auxiliary features, including sleep quality tracking, when used in conjunction with our companion mobile application, which is also expected to help bring *InfraStrjoke* to a larger market.

The invention and development of *InfraStrjoke* is expected to span 15 months with recruitment of a group of professional, including but not limited to senior software engineers, experienced specialists and competent product designers. The introduction of *InfraStrjoke* is predicted to prevent death caused by stroke, assist the medical treatment, such as the identification of the position of stroke, and monitor the health situation of the users. The data collected can be dedicated to medical research and development in the long run.

1 Problem Background

Stroke is a common disease in the entire world. Once a patient suffers from a stroke, millions of neurons are permanently damaged every single minute. It is of paramount importance that stroke patients can reach for help as soon as possible and receive medical treatment within the Golden Hour.

1.1 Definition and Types of Stroke

According to the American Stroke Association, a stroke occurs when the blood vessels supplying oxygen and nutrients to the brain are blocked by a clot or a blood vessel in the brain bursts [1].

According to the Centres for Diseases Control and Prevention, there are two major types of strokes: ischemic stroke and haemorrhagic stroke. An ischemic stroke occurs when blood clots or other particles like fatty deposits block the blood vessels to the brain, while a haemorrhagic stroke will occur when a blood vessel in the brain leaks blood or bust. There is also a transient ischemic stroke (mini-stroke), also known as a warning stroke, caused by a temporary clot [2]. The brain is the source of our memories, movements, as well as body functions like breathing and digestion. When a stroke occurs, the brain will not be able to receive oxygens and brain cells will start to die, causing sudden loss of language, dizziness and even death [3].

1.1.1 Strokes Cases Around the World

Stroke is a severe problem in the entire world. According to research by the World Health Organization, stroke is the second leading cause of death. Responsible for 11% of total death [4]. For every 6 seconds, a person dies from a stroke [5]. There is also a 22% fatality rate within a year of stroke [6]. This shows that stroke is a common yet deadly disease worldwide.

1.1.2 Strokes Cases in Hong Kong

When we look at Hong Kong's stroke cases precisely, stroke is also quite common among Hong Kong citizens, especially the elderly. People would have higher chances of suffering from strokes when they have unhealthy lifestyles. Many stroke patients may suffer from high blood pressure and high cholesterol level before they stroke [7]. Having these factors, citizens become more vulnerable to stroke. In fact, stroke was the fourth most common cause of death in Hong Kong, with around 3000 deaths and a 42% death rate yearly. On top of that, research done by the Stroke Research and Prevention Group of Hong Kong University shows that the number of "young stroke" cases has increased by 30% in the past decades [8].

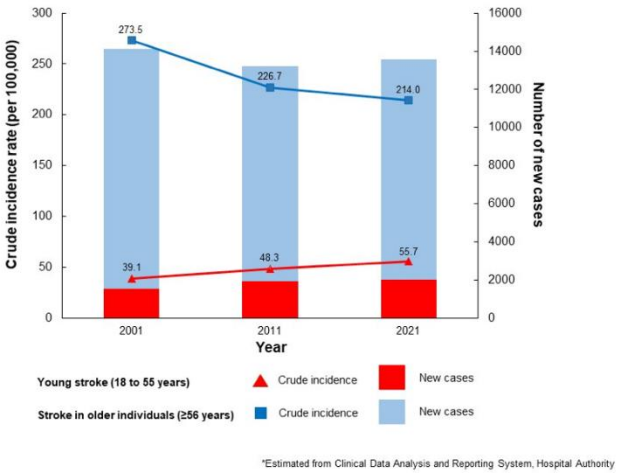
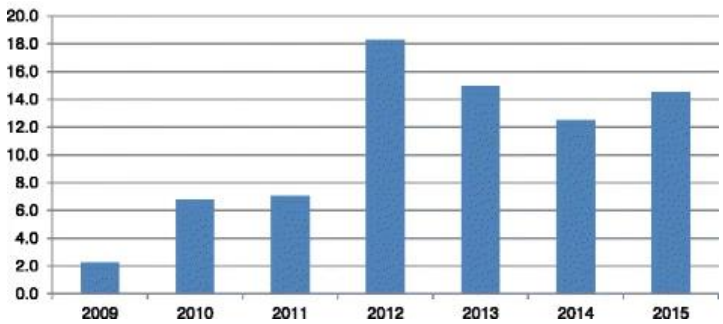


Figure 1
Crude incidence rate and number of new stroke cases in Hong Kong

1.1.3 Golden Hour of Stroke

The American Heart Association estimates that every single minute of stroke treatment delayed translates to the loss of 1.9 million neurons. In an hour, that patient's brain will lose as many neurons as it ordinarily would in over three and a half years of normal ageing [9]. This makes the golden hour of stroke relatively short, around 1-3 hours [10]. An analysis done by the American Heart Association states that 28.3% of the patients arrived within 60 minutes, 31.7% arrived 1-3 hours after symptoms started, and 40.1% arrived >3 hours after symptoms started. The effectiveness of intravenous thrombosis treatment decades by time for patients who arrived within 60 minutes and received intravenous thrombolytic therapy doubled the frequency compared with those who arrived in 61-180 minutes [11]. Unfortunately, according to a statistic journal by BioMed Central in 2019, only 73 out of 613 (12%) recorded stroke patients were able to arrive hospital and receive stroke treatment within 60 minutes from the beginning of a stroke. Although the percentage of IVT treatments within an hour has risen in the past two decades, the percentage is still relatively low.

Table 1: Percentage of Intravenous Thrombosis Treatment within the Golden Hour [12]



1.2 Proposed Solution

Chinese data show a steady decrease in in-hospital mortality following stroke, which may reflect improved immediate short-term stroke management over time due to advances in stroke treatment, including thrombolysis and patient care in acute stroke units [13]. It is believed that the sooner stroke patients arrive hospital and receive treatment, the lower the death rate and the milder the sequelae will be. This greatly inspired us, and we decided to invent a ground-breaking device that could detect strokes and alert the emergency services should one occur. With our product, *InfraStrjoke*, we would like to innovate something that can monitor the condition of blood vessels in the users' brains and warn them once they suffer from a stroke. Moreover, we would also want *InfraStrjoke* to be able to help them reach for help and receive treatment as soon as possible, within the golden hour. So, *InfraStrjoke* should be able to contact nearby hospitals automatically when our users suffer from a stroke.

1.3 Expected Effects

Due to stroke symptoms like dizziness, loss of language, and trouble seeing, it is tough for stroke patients to reach and help themselves. Our goal in inventing *InfraStrjoke* is to help stroke patients reach for help once they are suffering from stroke to shorten the time needed to arrive hospital. As a result, they will have a higher chance of receiving treatment within the golden hour. We believe with the usage of *InfraStrjoke*, the death rate of stroke would be decreased as *InfraStrjoke* can shorten the time they need to reach for treatment and save the lives of stroke patients.

1.4 Overview

Stroke is a severe problem all around the entire world. There is also a rising trend of stroke cases in the future years. For stroke patients, it is of paramount importance to receive treatment within the golden hour. Nevertheless, it can be challenging for stroke patients to reach for help themselves, and in the current market, no product can help them when a stroke occurs. Our product, *InfraStrjoke*, excels at stroke detection and post-stroke help-seeking. Devices with such functions have yet to be found in the current market. We believe *InfraStrjoke* is a ground-breaking product that can fill the gap of demand in the current market and, most importantly, save thousands of lives by warning users whenever a stroke occurs.

The following proposal will include the market positioning, market strategy, development timeline, and the physical and artificial intelligence of InfraStrjoke. Through this proposal, the accuracy, convenience and life-saving features of *InfraStrjoke* can be shown.

2 Proposal Context

2.1 Target Customer Profile

Based on our research, our targeted users are the elderly, those identified with a high risk of stroke, and those who are health conscious.

2.1.1 The Elderly

Considering the contemporary situation of developed regions across the globe, we can observe that a vast majority of regions have been suffering from an ageing problem, and Hong Kong is no exception. According to the information published by Hong Kong Census and Statistics Department, 19.3% of Hong Kong's population was aged 65 or above [14]. In other words, out of every ten Hong Kong citizens, approximately two are 65 years or older. Nevertheless, due to the hectic lifestyle of metropolitans, many elderly are forced to live solitarily despite living with their family member. In 2016, there were more than 130000 solitary elderlies [15]. If some accident occurs or some sudden health problem, such as unconscious caused by a stroke, in their house, they cannot be helped or transported to the hospital immediately. Thus, *InfraStrjoke* can provide some help for them during an emergency.

2.1.2 Identified High-Risk Stroke People

Metropolitans have sedentary lifestyles [16] and do not play sports, along with unhealthy diets, such as high salt and oil intake, and unfavourable habits, including smoking, all of which lead to a higher likelihood of blood vessel narrowing and hypertension. When the doctor identifies them as having a high risk of stroke, they will emphasise their health to prevent stroke or other serious illness. For instance, for those who are obesity, after seeking the help from doctor, it is expected that they will be willing to purchase our product for monitoring their health situations to see whether the solution is effective or not. Once they are suffering from stroke unfortunately, they can be transported to the hospital within the golden hour, protecting their life.

2.1.3 Health-Conscious People

Thanks to the increased educational level, more and more people understand how serious and how prevalence the diseases are. Thus, people's awareness towards health has been tremendously raised, paying more and more attention on their health. Some of them will be willing to purchase our product for health monitoring to observe any invisible abnormality in their body [17].

2.2 Current Technologies

We have isolated three stages in which technology can potentially act to aid stroke patients.

2.2.1 Stroke Prevention

Currently, there are some medication options available for stroke-vulnerable patients to take. Anticoagulants, or blood thinners, can prevent blood clots from forming due to atrial fibrillation, decreasing the risk of blood clots dislodging and causing an ischemic stroke (strokes caused by blood clots) [18]. However, due to its working principles, this medication is only effective against ischemic but not haemorrhagic strokes (strokes caused by internal bleeding). The same article also pointed out that taking blood thinners can cause bleeding from any wounds to take longer to stop, which could be very dangerous if the wound is large enough. Such medications can worsen a haemorrhagic stroke should one occur [19] and should not be prescribed to stroke-vulnerable patients as a blanket prevention measure.

2.2.2 Stroke Detection

Numerous fitness-tracking gadgets like smartwatches can also track users' heart rates and blood pressure. While cardiovascular health is a stroke risk factor, such products can only detect atrial fibrillation to a limited extent and cannot detect strokes at all [20].

2.2.3 Post-Stroke Help-Seeking

Gadgets focused on getting help, especially for the elderly, such as the *"Personal Emergency Link Service",* can connect the user to a hotline or emergency services at the press of a button [21]. However, this system requires manual input from the patient. Since strokes can cause confusion, numbness, and discoordination [22], it is often difficult, if not impossible, for the patient to call for help themselves. Some strokes can even be asymptomatic, where the patient would not notice it in the first place [23]. One can conclude that it is infeasible for the *PELS* or other manual help-seeking methods to be effective in the case of strokes.

2.2.4 Summary

From the above examples, one can observe that current technology is simply inadequate in stroke prevention, detection, or post-stroke help-seeking. This realisation prompted us to investigate the possibility of automatic stroke detection methods to trivialise the latter two stages and allow medical intervention as soon as possible.

3 Product Description

With the insights drawn from the current technology analysis, we have concluded that an effective stroke aid product must qualify the criteria above. Our product, *InfraStrjoke*, precisely excels at stroke detection and post-stroke help-seeking, filling a void in the current market.

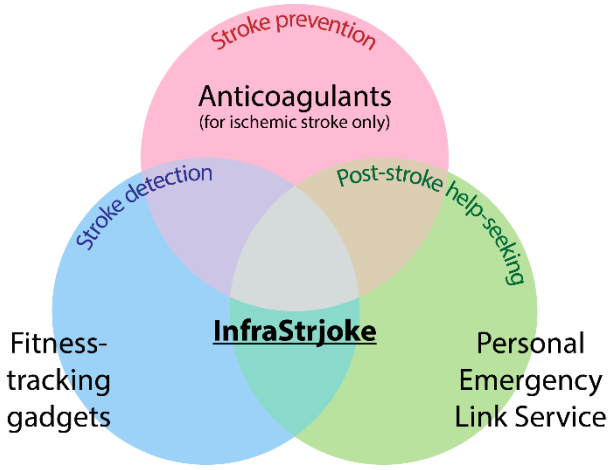


Figure 2
Venn diagram of important stroke aid factors against current market technologies. Note that some products only partially fit the criteria, as denoted by their partial inclusion.

3.1 Product Overview

InfraStrjoke is a smart headband designed to detect strokes and alert emergency services should one occur. In addition, *InfraStrjoke* also comes with a companion mobile application. Although the headband alone is sufficiently equipped to perform stroke detection and help-seeking, the mobile application can augment its capabilities and provide support for its auxiliary features.

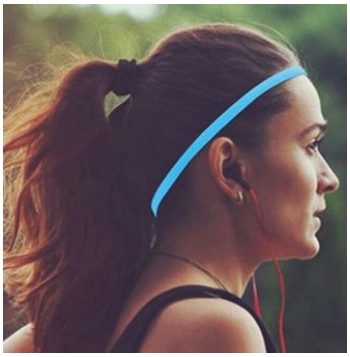


Figure 3
A model wearing InfraStrjoke

3.2 Primary Product Features and Working Principles

The following features are integral to the core functionality of *InfraStrjoke*.

3.2.1 Stroke Detection

InfraStrjoke utilises NIRS to image the blood vessels in the brain. The images are then fed to a CNN for clean-up and interpretation to determine whether a stroke has occurred.

3.2.1.1 Near Infra-Red Spectroscopy (NIRS)

Near infra-red refers to light just outside the visible range, with wavelengths between 750 and 1400 nm. NIR light is low-energy and poses no harm to the user even under prolonged exposure [24].

InfraStrjoke is fitted with two types of NIR sensors. The first type is at a wavelength of 850 nm. It is responsible for handling the majority of the imaging. This wavelength of NIR has the highest penetrative power with regards to the skull and brain tissue [24], with studies showing that it can penetrate up to 5 cm from each side [25] [26] [27], amounting to a total coverage of

roughly 89% of the head. This sensor type can provide an optimal image for further processing. The second type is at a wavelength of 730 nm, which is optimal for measuring the user's blood oxygenation and blood sugar; this type of sensor is currently widely used in pulse oximetry [28].

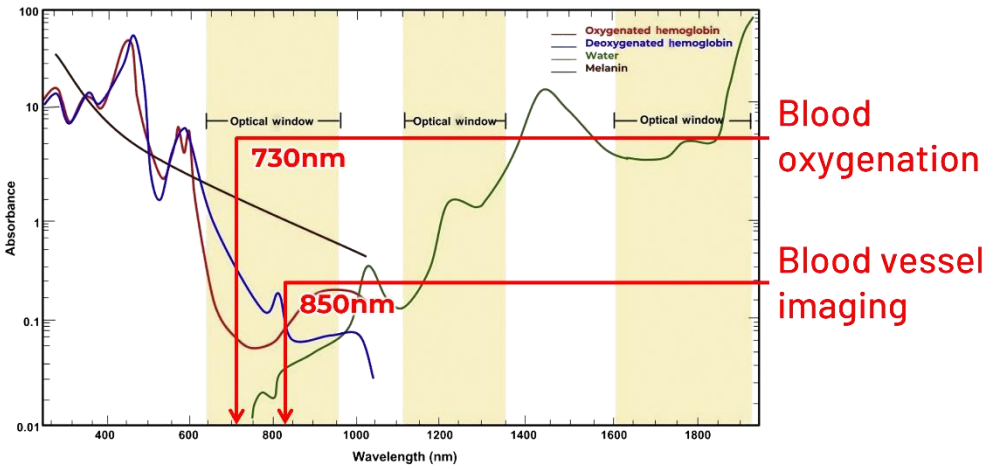


Figure 4
Two types of NIR sensors with their wavelengths marked on the absorption curves of blood (haemoglobin and water).

3.2.1.2 Convolution Neural Network (CNN)

The major drawback of infra-red imaging is its low image resolution compared to other forms of imaging, especially considering the environment is not controlled, which increases the difficulty of analysis. Considering this, the captured images are fed to a CNN for interpretation.

CNN is an artificial intelligence (AI) architecture designed to perform well at image processing tasks with very high speed and accuracy [29]. This technology is well suited to analysing medical images, such as MRI cancer screening and CT reconstruction [30], as demonstrated by its widespread use in hospitals. It is reasonable to expect it to be able to isolate important features like blood vessels from the potentially noisy images and subsequently use the data to detect both ischemic and haemorrhagic strokes with enough training.

3.2.2 Emergency Services Contact

After analysis, should *InfraStrjoke* detect a stroke, it will attempt to contact the emergency services. Every *InfraStrjoke* headband is equipped with Bluetooth, Wi-Fi, and LTE chips. We expect the user to connect *InfraStrjoke* with their mobile device via Bluetooth most of the time; nevertheless, we have opted to include the selection of chips such that *InfraStrjoke* can still operate independently for those who might not possess smart mobile devices, like the elderly. Distress calls will be made using the patient's phone via Bluetooth. It will also notify our partners, such as the Hospital Authority, through our specialised online internal distress system

to better their coordination. These chips can provide sufficient redundancies such that the patient can be guaranteed to still receive help in the event that one of the systems fail. In addition, an on-board GPS chip can provide paramedics with the precise location of the patient.

3.3 Auxiliary Product Features and Working Principles

The following features are not strictly necessary for the core functionality of *InfraStrjoke*; however, they can utilise the incorporated sensors to provide extra utility with little added cost to augment the desirability of *InfraStrjoke*. We believe they can bring *InfraStrjoke* from the niche of stroke detection products to a more general healthcare and lifestyle product to broaden our consumer market.

3.3.1 Sleep Quality Tracking

In addition to the conventional accelerometer, InfraStrjoke can utilise its blood oxygenation, pressure, and heart rate sensors to provide a more accurate sleep quality metric than most similar sleep-tracking products [31].

3.3.2 Fitness Tracking

InfraStrjoke can provide basic exercise tracking and analyse the user's exercise intensities, mid-exercise cerebral blood oxygenation, and post-exercise recovery rates to estimate their cardiovascular health. As will be discussed in *Health Monitoring & Stroke Prediction*, this feature is also expected to generate more data points for the algorithm to increase its accuracy.

3.3.3 Bone-Conduction Headphones

We thought it reasonable to embed a set of bone-conduction headphones [32] after considering the location of *InfraStrjoke*. This inclusion also presented the opportunity to introduce a premium model, *InfraStrjoke+*, for our more technologically inclined users without making the base features unaffordable to other customer groups like the elderly.

3.4 Companion Mobile Application

This free companion app can augment the headband's base functionality and support various auxiliary features.

Home screen Cerebrovascular Health Profile & Settings

Figure 5

InfraStrjoke companion mobile application interface

3.4.1 Medical Information

The app allows users to set up their personal medical information and act in conjunction with the Hospital Authority's eHealth system [33] to provide paramedics with essential information regarding the patient's medical history, allergies, and current medications *(Figure 5, Screen 3)*.

3.4.2 Emergency Routines

Users can also create routines in the case of emergencies *(Figure 5, Screen 3)*. The app will notify the patient's family members of their situation per their preferences.

3.4.3 Health Monitoring & Stroke Prediction

Throughout the day, *InfraStrjoke* continuously collects data about the user's vitals as its core functions demand. This data can be chosen to be sent to the app for real-time analysis. With the app, users can monitor their real-time vitals measurements *(Figure 5, Screen 1)*. In addition, it can notify the user of critical conditions, such as high blood pressure and low blood oxygenation.

Cardiovascular health is proven to be a significant risk factor for stroke. Those with cardiovascular diseases are estimated to have more than 20% risk of a stroke incursion within ten years [34], with heart rate irregularities and blood pressure variabilities identified as the two leading factors [35]. With the collected data, the app can draw the user's attention to any

detected cardiovascular irregularities and provide related knowledge and health advice. The data can also be used to extrapolate the probability of stroke in the near future and warn the user of imminent strokes should it exceed a certain threshold *(Figure 5, Screen 2)*.

3.4.4 Auxiliary Feature Support

As discussed in the previous section, further data analysis can be performed to provide sleep quality and fitness tracking. In addition, should the customer purchase *InfraStrjoke+*, the app can help their phone identify *InfraStrjoke+* as a set of headphones and provide some audio equaliser functions.

3.5 Headband Design

The core design principle of *InfraStrjoke* is to serve the user and allow them to comfortably wear it every minute of the day in hopes of providing round-the-clock stroke protection. To this end, we have designed *InfraStrjoke* to be ergonomic, flexible, and customisable.

Figure 6
InfraStrjoke headbands of different colours

With an ergonomic design and numerous size options, the headband can be guaranteed to fit the user perfectly. The primary material of *InfraStrjoke* is silicone, which is lightweight, flexible, and body-safe so that it is comfortable even when the user is sleeping. The exterior consists of a thin sleeve of interchangeable fabric to allow for cleaning. We also provide various colours and patterns for the sleeve to fit the user's preferences. To further its weatherability, *InfraStrjoke* is made to comply with the IP69 standards [36], such that *InfraStrjoke* can be worn even when the user is taking a shower or even swimming.

4 Product Development Plan

This section details the development cycle of *InfraStrjoke*. Its development will follow the IDEO circular product design and invention model [37] [38]. Following this model, we focus on understanding the need in the market and observing targeted users' behaviour while invention, thus inventing a tailor-made product for them. The entire product development, from initial design of the headband which including infra-red stroke detection system to the AI

model for the calibration and complementary mobile app, is estimated to last fifteen months of labour with an estimated cost of HKD 3,000,000. This development plan contains three sub-sections, *Expected Challenges*, which elucidates the obstacles during our product invention and the solution of it, *Required Resources*, which includes a generalised list for the required resources and the corresponding costs involved, and *Development Timeline*, which introduces the four phases with detail for our product development .

4.1 Expected Challenges

Analysing the technology and current market, our team identify three major challenges. The distribution of the infra-red system, which affect the stroke detection, AI calibration of CNN function, which quantified the data from the head, and the product positioning. Having these expected challenges, our development plan and required human resources will be unique and different from those app development or typical electronic gadgets development. Specialist, who is responsible for researching infra-red system, quality assurance testers which is responsible for collaborating with specialist, and tester coming from general public will be recruited for the IDEO development approach.

4.2 Required Resources

Our team is requesting a total funding of HKD 3,051,921 for the development of *InfraStrjoke*. The expense breakdown is as follows.

Table 2: Breakdown of expenses during development

Item	Monthly cost (HKD)	Months Required	Total Cost (HKD)	Objective
Software Engineers (×2)	32,000 per person [39]	15	960,000	To design an Artificial Intelligence for stroke detection and self-calibration, unit testing, debugging, and the invention of a complementary mobile app.
Specialists (×2)	24,000 per person [40]	15	720,000	To find the appropriate position and distribution of the infra-red system and the most comfortable material for users by experiments.

Product Designer	22,000 [41]	15	330,000	To design an ergonomic product.
Quality Assurance Testers (×2)	22,000 [42]	15	660,000	To test the function of our testing product during development.
First Stage Prototypes (×10)	2,000	N/A	20,000	To perform initial integration during prototyping for setting the fundamental function.
Preproduction Prototypes (x30)	5,000	N/A	150,000	To integrate the design and software for testers and troubleshooting during application.
Testers (×30)	2,000	N/A	60,000	To wear our product for testing the functionality of *InfraStrjoke.*
Marketing Officer	17,550 [43]	8	140,400	To formulate a promotion plan for *InfraStrjoke* to our target audience and enterprises for collaboration and partnership.
Advertisements	10,000 [44] [45]	9	90,000	To promote *InfraStrjoke* through Google search, social media, and bus advertisements in Hong Kong.
Apple App Store	2,326 per annum [46]	12	2,326	
Google Play Store	195 (One-time) [47]	N/A	195	
Total			**3,051,921**	

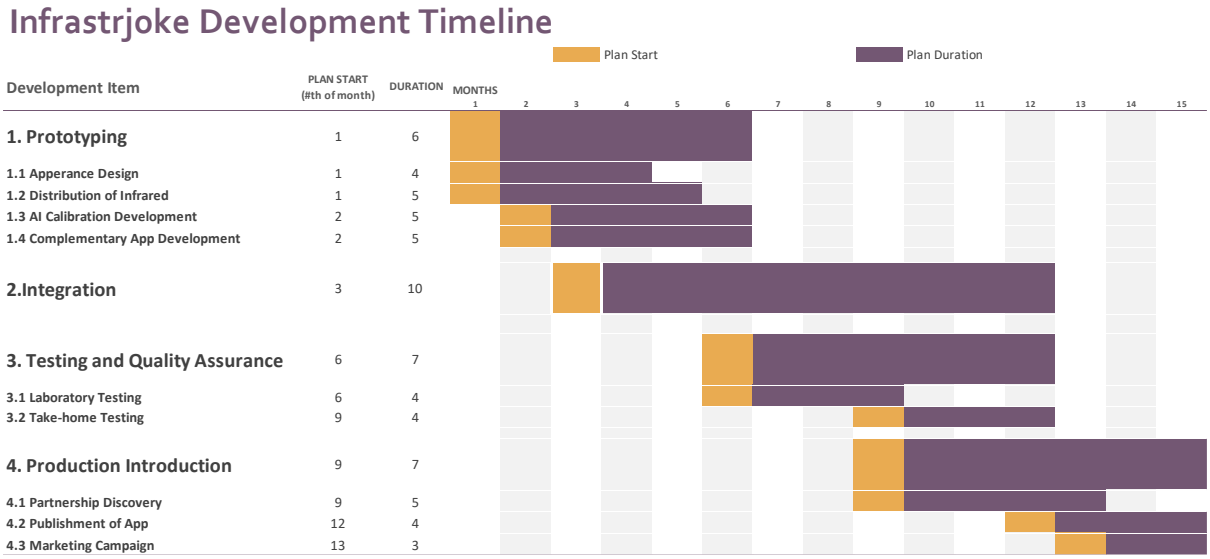
4.3 Development Timeline

4.3.1 Overview

The development plan of *InfraStrjoke* consists of four phases, following the IDEO product invention model. The four phases are prototyping, integration, testing and quality assurance, and product introduction.

The figure below is a Gantt chart demonstrating the expected timeline for the four phases of *InfraStrjoke* development, from the initial prototyping phase to product introduction to the market. The expected starting month and duration of the phase is colour-coded in the Gantt chart below with some description and detailed explanation. With the IDEO product invention model, each phase is closely intertwined and may concur simultaneously in some periods.

Table 3: Gantt Chart of *InfraStrjoke* development phases and timeline



4.3.2 Phase One: Prototyping

During prototype development, our product designer is tasked with designing the appearance of *InfraStrjoke*, and our specialist with finding out the most appropriate distribution of the infra-red system by the design and the skull size of our team members and quality assurance testers. With the blueprints and specifics of the infra-red detection system, our software engineers will work on CNN development to analyse the collected data in addition to the companion mobile app. Following the IDEO product invention model, this stage allows our team to collect feedback from the tester and continuously ameliorate the product. The functionality developed in this stage will include basic infra-red stroke detection and AI calibration.

4.3.3 Phase Two: Integration

At this stage, alpha and beta versions of *InfraStrjoke* will be produced. Our product in this phase is capable of stroke detection by the system developed in phase one, users positioning by embedded GPS chips and complementary mobile app providing users' information and health monitoring function.

4.3.4 Phase Three: Testing and Quality Assurance

Testing and quality assurance will begin with laboratory testing (short-term), including strenuous exercise testing, fake skull testing and take-home test (long-term), such as health monitoring and app function testing. It is expected that many application problem will occur in this period. The shortcoming and bug of the product will be found in this stage. Troubleshooting and amelioration for *InfraStrjoke* will be recirculated until no bugs and problem is found.

4.3.5 Phase Four: Product Introduction

InfraStrjoke will be introduced to the market from month nine of phase three. When *InfraStrjoke* is mature enough, equipped with fundamental features, such as precise stroke detection, up-to-date health monitoring and smooth complementary app, our team will unearth some collaboration with enterprises or organisations to sell to the targeted customer. It is expected that hospital authority and the elderly home, such as The Hong Kong Society for the Aged, will be the major partner for us, targeting the identified high-risk people and the elderly. Once our product is well-prepared, i.e. complementary apps are published in App store and Play Store, our team will start marketing campaign in digital and in person aspect. In digital approach, Google search advertisement, which shows some pop-up screen designed by our marketing officers, registration of social media business account, such as Facebook and Instagram, and advertisement on the social media, including suggestion of our product in the stories and posts. In physical way, several advertisements will be posted on the bus body for exposing to more citizens.

5 Conclusion

To conclude, we are greatly inspired by the seriousness of stroke that it is the second leading causes of death among the entire world, responsible for 11% of total death. On top help that, realising the fact that those stroke patients are not likely to be able to seek immediate help themselves also motivated us. As inspired, we started our invention on *InfraStrjoke* and would like to warn those patients at the very beginning of their stroke and help them to reach for

medical treatment. We definitely have the passion and the enthusiasm on developing *InfraStrjoke* and helping those who suffer from stroke. There is no such product that is like *InfraStrjoke* in the current market, thus *InfraStrjoke* would have its unique marketing and would be able to save thousands of lives.

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7 Work Allocation

Section	Person
0 Executive Summary	Martin + Ka
1 Problem Background	Kart
2 Proposal Context	Martin + Ka
2.1 Target Customer Profile	Martin
2.2 Current Technologies	Ka
3 Product Description	Ka
4 Product Development Plan	Martin
5 Conclusion	Kart