Seun Omolade, Ph.D

Digital Marketing and Brand Performance

Analysis of Selected Diabetes Apps

Master's Degree in International Business Management

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KAMK • University of Applied Sciences

Abstract

Background:

With the increase and rapid proliferation of mobile health (mHealth) apps, clinical validation efforts are well ongoing to provide guidance and information to health care providers and the public about which products rely on evidence-based medicine. However, there is not much with regards to the market and brand performance of these apps.

Objective:

The overall objective of the thesis is to validate some selected diabetes apps regarding the needs of their users; and analyse both the value and market performance of these selected apps.

Methods:

Diabetes apps were identified from three app platforms namely, SlideME, Google Play Store and Apple app store. Selection was done using content analysis technique with focus on the PRECEDE-PROCEED Model (PPM) and Digital Health Scorecard. For analysis, sentiment analysis, value and market performance analysis were done.

Results:

1100 apps were obtained from the three app platforms, with 37 apps passing through the two selection stages. However, using the number of available reviews per app and Digital Health Scorecard as criteria, only two apps were used for further analysis.

For the sentiment analysis, about 1000 reviews were extracted for both Glucose Buddy Tracker app and Carb Manager app. 54.1% and 69.5% of the reviews were categorized as positive for Glucose Buddy Tracker and Carb Manager app respectively. In contrast, 14% and 16.7% of the reviews were categorized as negative for Glucose Buddy Tracker and Carb Manager app respectively.

The BAR and PAR values of both selected apps were very low indicating that the apps are not optimally performing in the conversion of their users' awareness for both performance action and advocacy. However, at +83% Net Sentiment Score (NS) the overall sentiment for both apps were positive. In addition, as part of brand equity the co-occurrence results, which is an indication of brand association, using positive reviews indicate that for both apps the overall positive NS score is associated with the usage of the app and other functional benefits involving tracking and logging of blood glucose values.

Conclusions:

This research confirms that there is the possibility to develop a framework combining both theoretical models and brand performance models to be able to validate the performance of mobile apps. In addition, for matured indication like diabetes, the finding indicates the potential value the diabetes app provides in the self-management of diabetes. Relatedly, the use of digital health apps provides a welcome and needed comfort to both healthcare providers and the patients towards a value delivery form of healthcare.

Key findings

1. For both selected apps, there was a significant increase in positive reviews that coincided with the app version upgrades. The app upgrade is a form of a change in the brands' marketing strategy.
2. The value and market performance of both apps by comparison are very similar, an indication of both brands using similar strategy to navigate their industry landscape.
3. Both apps did not meet the defined usability and user-requirement needs of their targeted users.

Author: Omolade Seun, Ph.D

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1 Introduction

Digital health is a new emerging field that is a result from the evolutionary steps in the interaction between healthcare and information and communication technology (ICT); and with digitally aware customers (patients) in the middle of this intersection. The customers at the centre of this interaction signifies an important characteristic of digital health, which is that this emerging field is to some extent largely driven by customers. However, these customers expect that the work procedure and workflow of digital health companies are designed to adapt to their lifestyles and patterns digitally. In essence, digital health is a new field that encompasses areas like innovation, evidence, and adoption. Moreover, the main difference to the older form of health technological advancement is not in the technology itself, rather the readiness and the level of the adoption and absorption of these technologies into people's normal lives, thinking and expectations.

Moreover, there is high expectation with regards to the expected value the field of digital health will bring; and already the global digital health is valued as an over 200 billion U.S. dollars industry in 2020 and the global mobile health (mHealth) amounted to about 28 billion U.S. dollars (Rooney, Rimpiläinen, Morrison, & Nielsen, 2019). For simplest explanation, mHealth is one of the components of the digital health ecosystem that relies on mobile technologies and smartphone applications (digital apps) to deliver better value for health. There are currently several of such digital and mobile apps employed in different health care challenges, like in diabetes (e.g. MySugr), mental health issues (e.g. moodfit), cancer (e.g. CareZone), and cardiovascular diseases (e.g. Instant Heart Rate).

Diabetes mellitus (DM) is one of the top 10 causes of death globally, with an estimated 451 million adults living with the disease worldwide in 2017 and projected to increase to about 693 million by 2045, if no preventive methods are adopted (Ojo, 2016). Relatedly, empirical evidence shows that there are several benefits with the use of mobile digital apps for the management of diabetes. Already, DM-specific mHealth apps had been installed approximately 67 million times, with approximately 15 million installations in 2018 and 46.3 million installations in 2019, which represented approximately 11% of patients with DM diagnoses worldwide in 2019 (Ojo, 2016).

With this viewpoint, businesses will benefit if there is a data driven framework to evaluate the market performance of mobile applications addressing disease indications, including DM-specific mHealth apps.

1.1 Objectives and Research Questions

Several studies have already focused on the clinical effectiveness of some medical specific apps and on some of the available DM-specific mHealth apps. Therefore, the overall aims of this thesis are to validate some selected diabetes digital apps to see if it satisfies the needs of its targeted patients. In addition, to analyse the performance of the different digital marketing strategies employed by these selected diabetes apps. The two aims tied directly to the overall purpose of the research work, which is to develop a framework that focuses on satisfying the two main objectives of the study. These two main objectives of the study are:

1. To analyse and validate the selected DM specific apps towards meeting the needs of diabetes patients

2. To analyse the value creation model and marketing performance of the selected diabetes digital apps

Consequently, the practical and business importance of these objectives to the commissioner is to develop a framework that will serve as the operational backend towards developing a digital platform. With a framework developed, the commissioner can develop a digital platform that is capable of self-analyzing mobile applications and extend the finding to the brand performance evaluation of mobile applications in other industries.

From this viewpoint, there are three research questions:

a. How has the customer's sentiment and perception change with the different digital marketing strategies of the selected apps?

b. How does the marketing performance, in terms of value creation, of the selected apps compare among themselves?

c. Did the selected Apps meet the needs of the targeted patient group? How?

The commissioner company is a health-tech and business coaching start-up venture that is developing digital solutions for healthcare industry, and one of such solutions is to address healthcare challenges related to health service accessibility during emergency.

Moreover, the study was conducted using case study with multiple cases (top apps were selected) and embedded focus involving more than two validation criteria as the research strategy. The research approach was abductive; and the employed philosophy was pragmatism with an

interpretivism view. The interpretivism view considers the reasons and motives of human behaviour, arguing that the understanding of reality happens via social constructions and social interactions. For this research project, the interpretivism view was used because the themes of the research consisting of digital health and digital marketing are some of the indirect factors influencing consumers, who themselves are social actors in the whole dynamics. In addition, the way the customers respond to these external influences also play a significant role in shaping the overall dynamics.

Furthermore, mixed research method was used, and the primary data sources were different relevant literature sources, digital app stores, webpage, and relevant business reports of the selected apps. Data analysis done included content analysis, sentiment analysis, digital health scorecard for mobile app validation, and digital marketing performance metrics analysis, mainly Purchase Action Ratio (PAR), Brand Advocacy Ratio (BAR). In addition, value analysis of the selected DM apps was performed.

The justification for this developmental research work is that with the availability of hundreds of thousands of different digital health apps, it is important for experts to have an empirical study evidencing the validity of some of these apps, especially within a matured and developed clinical indication disease like diabetes. In addition, the result of this research will provide a future operational framework for the commissioner of this project; and help towards advancing the mission of the company. Moreover, analysing both the performance and value of the selected diabetes digital apps could serve as a knowledge base that could be utilized in other digital apps of different therapeutic areas.

1.2 Research Strategy

The choice of most research strategies is guided by both the objectives of the research and the research questions (Saunders, Lewis, & Thornhill, 2009). In this research work, case study was the research strategy of choice. Case study strategy is the ideal choice when it involves studying a phenomenon within its real-life context; and the boundary between both the phenomenon and real-life context are not evidently clear. In addition, data collection in case study usually involves various methods and requires triangulation of data collection techniques to ensure accurate data analysis and interpretation.

2 Digital Marketing and Innovation in Value Creation

Digital marketing, according to the American Marketing Association (AMA 2022), is a term for marketing of products and services using the power of the internet and other digital technologies. From this definition, digital marketing can be viewed as a subtype of traditional marketing.

Digital marketing first came into existence in the 1990s, coinciding with both the dot.com era and the birth of the first search engine (Cecilia, 2019). In addition, this period was also synonymous with scholars alike theorizing a shift in traditional marketing to a flow-like state and characterized with optimal experience of the consumers when surfing the web for products, or as an interactive online shopping at the comfort of consumers' home despite the cross-channels and logistic concerns at the time (Rindfleisch & Malter, 2019). Furthermore, this period also ushered in the development of strategies to optimize the placement of webpages in search results, also known as Search Engine Optimization, (SEO) (Cecilia, 2019). From the 2000s however, things developed rather rapidly with social media coming into focus and search engines becoming more personalized and very intuitive. Thus, digital marketing is a new phenomenon that arose with the advancement and the convergence of technology and the multiplication of devices that are always connected online, to develop new approaches to market online (Piñeiro-Otero & Martínez-Rolán, 2016). Unlike traditional marketing, digital marketing as a new concept requires a different form of strategy.

2.1 Strategic Digital Marketing

From strategic marketing point of view, digital marketing is a new form of marketing developed on the premise of improved strategic marketing and digital technology, especially big data technology, and encompassing a digital platform to integrate these technologies and applications for operational purposes (Kotler et al., 2020). On the other hand, a strategy at its basic form is a hypothesis. Thus, a good strategy must therefore diagnose and identify the problem at hand, set a guiding principle to solving this problem and propose a set of coherent actions, which will deliver these principles (Rumelt, 2012). Strategies and business models are the pivotal blocks that businesses use to make profit (Visser, Sikkenga, & Berry, 2019). Combining both concepts of strategy and digital marketing, strategic digital marketing is the set of strategies aimed at promoting a brand in the digital environment, mostly on the internet by using different digital channels and methods (Pinto & Guarda, 2020). Against this background, as most industries of this

present era are contending with the digitalization forces in their environment and the customers are becoming savvier digitally thereby spending most of their time online, formulating a strategy to market in this digital environment becomes a must.

Digital environment in marketing is divided into micro- environment and macro-environment (Camilleri, 2017). In the micro-environment, the forces that play a defining role are the customers' online behaviour, digitally savvy customers, and the marketplace. However, on a broader scope the defining feature of a digital environment are the new emerging technologies or upgraded version of older technologies that causes digitalization around information exchange, client interaction and data storage (Kotler, Cao, Wang, & Qiao, 2020).

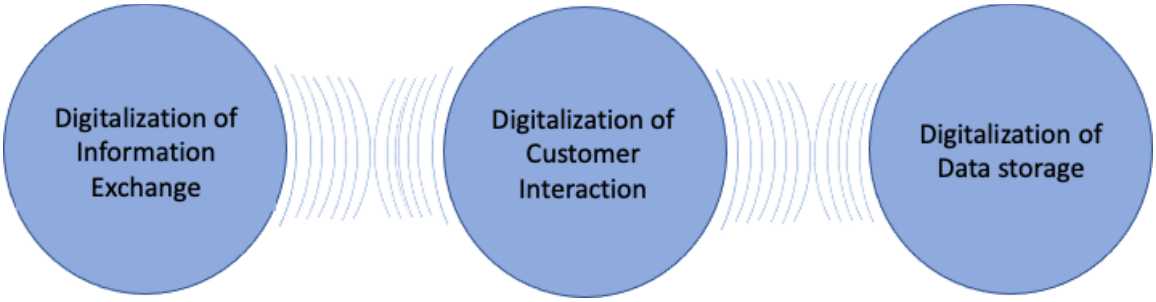

Figure 1. Diagrammatic representation of features of a digital environment (Kotler et al.)

Moreover, most customers in the digital environment are digitally capable and have shortened attention timespan. This shortened attention timespan is also a reflection of the shortened decision journey taken by digital customers during the process of making a purchase, termed digital customer decision journey (Kotler, et al., 2020). The digital customer decision journey is an upgraded classical traditional customer decision journey (CDJ), which with the help of digital marketing tools shorten customers' time of evaluating and enable customers to repurchase just out of the preference of brands, thereby forming the loyalty loop (Figure 2.).

Apps as a tool of Information Exchange Digitalization

One of the most important tools for digitalization and information exchange is the mobile app, because for every 8 minutes users spent on their phone, 7 minutes are spent accessing mobile apps (Global Trends in Mobile Advertising, 2016). Moreover, with customers spending 80% of the time spent on mobile device on apps (average time consumer spent on mobile devise is 2 hours and 31 minutes), specialized apps are becoming the primary main source of information exchange for brands on the internet (Dwivedi et al., 2021). In addition, investing in specialized apps brands

have opportunity to direct customers to more specific action targets and at the same time provide a simplified user experience (Kotler et al., 2020).

2.1.1 What is Innovation

Innovation is a transformational process that is brought about because of demands, either competitive demands from competitors or demands from customers for better and new product offerings (Ramadani & Gerguri, 2011). Several authors agree that innovation as a concept is multifaceted and can be confusing to accurately define. However, to give an accurate description of what innovation is one must consider the four separate elements, namely product, processes, services, and management (Ramadani & Gerguri, 2011). Thus, this basis of categorization shows that innovation entails adding values to both tangible and intangible substance (Wainwright, 2009). On this basis, innovation could be defined as the process of making changes to products, processes and services that results in the introduction of something new that is of additional value to customers (O'Sullivan & Dooley, 2008).

Furthermore, the other important feature of an innovative change is novelty in the marketplace (Wainwright, 2009). The two features of novelty in the marketplace and value creation are the key concepts that define innovation, and separates it from other forms of change, like invention and discovery. In contrast, invention and discovery increases knowledge but it is not marketable as a ready-made product and service (Wainwright, 2009). Ramadani & Gerguri, (2011) identified in general four types of innovation:

Incremental innovation

This kind of innovation exploits existing technology with focus on improving the costs or features of existing processes, products, or services. The incremental innovation type is often employed by businesses to improve and balance their portfolio in response to competitive forces in the marketplace.

Additive innovation

It focuses on fully exploiting existing opportunities that are characterized with small risk, and often pursued when there is a high chance such innovative endeavour can achieve good result.

Complementary innovation

This innovation type focuses on offering something new that does not necessarily change the structure of the existing businesses in the marketplace. Thus, most future, next-generation complementary innovation often revolves around the core product line or services of the business.

Disruptive (also termed radical) innovation

These are highly uncertain, emerging new forms of innovation that focus on creating dramatic change that can transform existing market or creates a new core product and service. This innovation type creates new possibilities.

Depending on the goals or objectives of the business, organizations or businesses often engage in the above listed different innovation types. Moreover, there are other drivers of innovation that influences the choice of these business goals and objectives. Often, these sources of innovation or innovation drivers ensure that organizations and businesses engage in a continuous learning and innovative ideas generation process (O'Sullivan & Dooley, 2008). There are four of such drivers of innovation, namely:

- Emerging technologies
- Actions of competitors
- Ideas from customers, suppliers, partners
- Emerging changes in the external environment

Established businesses in the past spend billions of dollars in revenue for internal research and development capabilities (R&D). However, in today's reality the speed of new emerging technology is too fast for any internal capabilities to develop alone (O'Sullivan & Dooley, 2008). A case in point is blockchain technology. In response to this new reality, resources are now expended towards scanning external business environments, like universities, start-ups, competitors for such emerging technology (O'Sullivan & Dooley, 2008). Furthermore, paying attention to competitors can provide a quick benchmark on which direction the company is to focus on in the future or pay close attention to. Similarly, demands from customers or reviews and feedbacks from trusted suppliers and partners could serve as a pointer. Such feedbacks are valuable mainly because they are externally derived sources of innovative information.

2.1.2 Market Performance in Digital Environment

Value creation in business is essentially about satisfaction. It requires satisfying all the keyholders such as, the customers, suppliers, and employees; and ultimately understanding the relevance of their perspective to the organization's purpose and strategy and how to balance these needs and expectations (Company, Koller, Goedhart, & Wessels, 2020). Thus, from the targeted customer's perspective this relates to being aware of the brand of the business as strong brand awareness, both online and offline, is the ultimate target of all businesses. Accordingly, businesses need to have a unique offering and stand out to be able to have a strong brand awareness. Consequently, developing more touchpoints do not necessarily translate to this goal. To be able to achieve a strong brand awareness, companies should map the customer path to purchase, and strategically intervene in some selected critical touchpoints (Kartajaya, Kotler, & Setiawan, 2016).

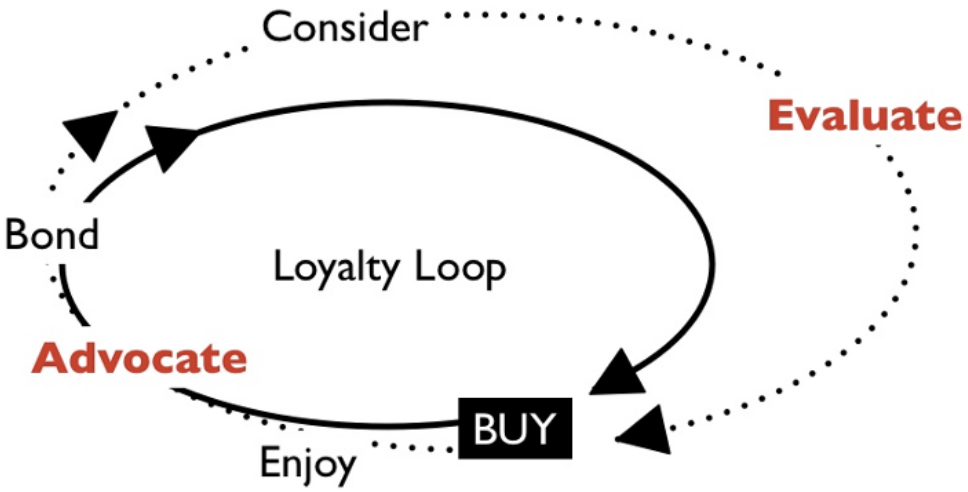

Figure 2. A typical customer journey map and a loyalty loop formed with the help of digital marketing tools that shortens customers' time of evaluating and enable customers to repurchase just out of the preference of brands (Edelman & Singer, 2015).

In traditional marketing, the 4As framework was developed to describe and evaluate customers' decision-making process when evaluating a brand. The 4As stand for: *Aware*, *Attitude*, *Act* and *Act again*. It also reflects the personal path of individual customers as they make their buying decisions. In summary, this is a very simple straight forward linear-like process (Kartajaya et al., 2016).

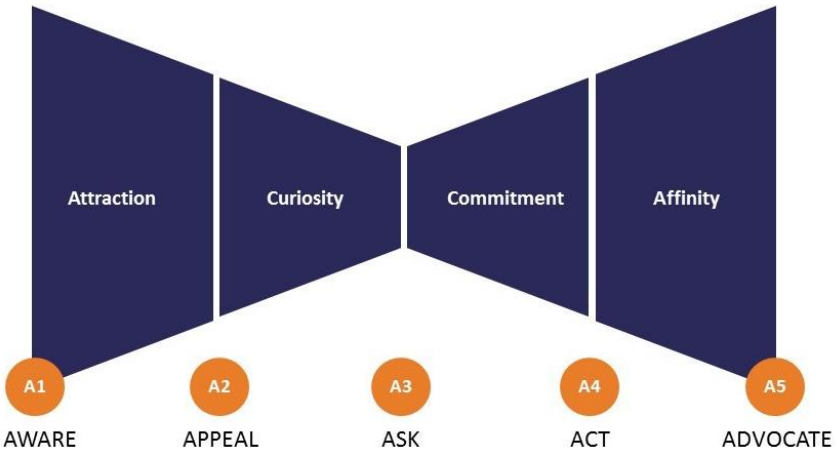

Figure 3. The ideal customer journey path of customers in a digitalized connected environment. Source: (Kartajaya et al., 2016).

In the current digitalized environment however, customers' decision is now largely influenced by the online social community of the customer; and loyalty is now ultimately defined by the willingness to advocate for a brand (Kartajaya, Kotler, & Setiawan, 2016). Based on the overall impact of internet connectivity, the 4As framework is not optimal any longer, rather a new framework has been proposed, called five As: *aware*, *appeal*, *ask*, *act*, and *advocate* (Figure 3) (Kartajaya et al., 2016).

2.2 Brand Equity Model and Value Creation

The impact of the perception of a brand in customers' buying decision is enormous, such that a brand name is not only a differentiating factor, but also used to justify the purchase decision (Nasir, Shamsuddoha, & Nedelea, 2010). Historically, a brand has been considered as only a 'name', 'logo', that serves a differentiating factor for companies. Recently, however, a brand is viewed to confer in addition a perceived value and personality to a particular product (Naeem & Sami, 2020). However, this is only possible when a brand has a strong brand equity. In essence, the fundamental competitive approach is to ensure a brand becomes capable of adding the sort-after perceived value to its customers by developing a strong brand equity. Brand equity is equal to the value created.

A brand equity is a set of assets and liabilities that develop into a differential effect for a brand, and which is perceived by customers when marketing the product or service of the brand (Civelek

& Ertemel, 2019). Thus, based on several research studies a brand equity is the most important intangible asset of a company with the capacity of improving the financial performance of the company (Nasir et al., 2010). Moreover, there are several models that have attempted to decompose the composition of a brand equity.

However, this research work describes the model from Aakers (1991), and further analysis was also based on this model. Aaker Model was named after David Aaker, who developed the model. The Aaker model consists of five components:

1. Brand loyalty

This is the deep commitment to rebuy a product or service despite situations that might prevent such committed behaviour. Brand loyalty can be reflected in factors like reduced marketing cost as it takes lesser time and cost to keep loyal customers, favourable response towards new brand-stimuli because loyal customers are not quickly swayed (Civelek & Ertemel, 2019).

2. Brand Awareness

The is the measure of how much or the extent to which a brand is known among the public. It can also be defined as the ability of a potential buyer to recognize or recall a brand spontaneously (Naeem & Sami, 2020).

3. Brand Association

These are those features triggered by the brand. There are three categories of brand association, namely attributes, benefits, and attitudes. Brand attributes are tangible features of a brand. And the attributes can often be product and non-product related. Benefits are associated values of the brand (Nasir et al., 2010).

4. Perceived Quality

This is the quality of product or service that a brand is associated with, and as perceived by the customer.

5. Proprietary assets

These are assets, like patents, intellectual property rights, trademarks, etc. that belongs to the brand.

Brand Performance Metrics in Digital Marketing

There is a necessity for all brands to preserve their intangible asset, i.e. their equity. Likewise, there is a necessity to measure the performance of a brand in the marketplace. The brand performance can be viewed as the determinant and evaluator of brand success in the market, which is also a useful factor in helping the brand achieves their business goals (O'Cass & Ngo, 2007).

There are different types of performance and systematic metrics developed to be able to track the progress of a brand as customers go through the decision-making path towards making a purchase. These metrics also measure the performance of the brand and any other digital marketing strategies implemented, with focus on the business goals to be achieved (Kotler et al., 2020). As such, Kotler et al., (2020) described two categories and these are:

a. Performance metrics measurement based on social media, such as Purchase Action Ratio (PAR), Brand Advocacy Ratio (BAR), Affinity index etc.

Purchase Action Ratio (PAR): This is the percentage of people in the market who spontaneously recall the brand when asked about it.

PAR = Action / Spontaneous Awareness

Brand Advocacy Ratio (BAR): This is measure of loyalty. It measures how many people are aware of the brand and can spontaneously recommend it.

BAR = Advocacy / Spontaneous Awareness

Affinity index: This is an efficiency metrics. It measures the extent a feature or category of a marketing medium matches the target audience. It is calculated thus:

Affinity Index = % of interested target / % of interested people in platform's entire population

b. Performance metrics measurement based on the consumer purchasing act, such as customer churn rate etc.

Customer Churn Rate: This is also called attrition rate. This is the natural business cycle of losing and acquiring new customers.

Customer Churn Rate = (Customer number at the beginning of the month – Customer number end of the month) / Customer number at the beginning of the month

To answer the research questions of this research work, we will focus on BAR, PAR, Net Sentiment Score, and sentiment analysis.

2.3 Health Behavioural Change Theories

It is no doubt that the adoption of mobile technology in healthcare (mHealth) is accelerating. The application of mHealth in the healthcare has expanded from healthcare support to the management of chronic conditions(Cho, Lee, Islam, & Kim, 2018). With the rapid and high coverage of mobile communication and the burden of noncommunicable diseases currently outweighs that of communicable diseases in both developed and developing countries, mHealth could be the panacea to reducing the current global burden of diseases through effective management of chronic diseases (Cho et al., 2018).

However, for better health outcomes mHealth interventions and products should be based on relevant health behavioural change theories that would be most appropriate for both the targeted disease indication and the thought-out intervention strategies. In theory, health behaviour change theory is a group of theories that aims to explain and structuralize the determinants of health behaviour (Cho et al., 2018). There are about 53 of such health behaviour change theories. Interestingly, most of these identified theories have overlapping key elements that differentiate them from each other (Ratz & Lippke, 2021). Cho et al., (2018) already identified five studies incorporating these theories using mHealth intervention and products.

Over the years, behavioural scientists have engaged in development and evaluation efforts that saw to the evolution of these theories, each targeting different key elements (Rejeski & Fanning, 2019) (

Table 1).

Key elements of the theory	Definition	Some Applicable Theories of Behaviour Change	Strategies of Applicable Theory for Behaviour Change
Threat	A danger or harmful event of which people may not be aware	Integrative Model (IM), health belief model (HBM), protection motivation theory (PMT)	Raise awareness that the threat exists, focusing on severity and susceptibility.
Fear	Emotional arousal caused by perceiving a significant and personally relevant threat.	IM, Elaboration Likelihood Model (ELM)	The basis that fear is a powerful motivator capable of initiating action from people.
Response Efficacy	Perception that a recommended response will prevent the threat from happening.	IM, HRM, PMT	Provide evidence of examples that the recommended response will avert the threat.
Self-Efficacy	An individual's perception of or confidence in their ability to perform a recommended response.	IM, transtheoretical model of behavior change, protection motivation theory (PMT)	Raise individuals' confidence that they can perform response and help ensure they can avert the threat.
Barriers	Something that would prevent an individual from carrying out a recommended response.	Social cognitive theory (SCT), HBM	Be aware of physical or cultural barriers that might exist, attempt to remove barriers.
Benefits	Positive consequences of performing recommended response.	IM, HBM, PMT	Communicate the benefits of performing the recommended response.
Subjective Norms	What an individual thinks other people think they should do.	Theory of reasoned action (TRA), IM	Understand with whom individuals are likely to comply.
Attitudes	An individual's evaluation or beliefs about a recommended response.	Self-regulatory model (SRM), integrative model (IM), health belief model (HBM), health decision model	Measure existing attitudes before attempting to change them.
Cues to Action	External or internal factors that help individuals make decisions about a response.	HRM	Provide communication that might trigger individuals to make decisions.

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Table 1: Factors targeted by health behaviour change theories. Adapted from Rejeski & Fanning, (2019)

Detailed explanation about most of these theories has already been done (see Brew-Sam & Chib, 2020; Cho et al., 2018; Ratz & Lippke, 2021; Rejeski & Fanning, 2019). For this thesis work, only the PRECEDE-PROCEED model will be further discussed in detail.

2.4 The PRECEDE-PROCEED Model

Towards the end of the 20th century many infectious diseases become eradicated leaving only Non-Communicable Diseases (NCD) as the leading cause of mortality. Consequently, the focus of health maintenance and quality of life shifted to both the prevention of these diseases as against the preventive measures earlier undertaken and the promotion of behaviours and attitudes that promote and maintain healthy lifestyle and quality of lifestyle ("Chapter 2. Other Models for Promoting Community Health and Development | Section 2. PRECEDE/PROCEED | Main Section | Community Tool Box," n.d.).

Within this framework and awareness, one of the models developed with this assumption about the prevention of health and the promotion of health was PRECEDE-PROCEED Model (PPM) in 1974 by Lawrence Green. PRECEDE-PROCEED are acronyms: PRECEDE stands for Predisposing, Reinforcing, and Enabling Constructs in Educational/Environmental Diagnosis and Evaluation.

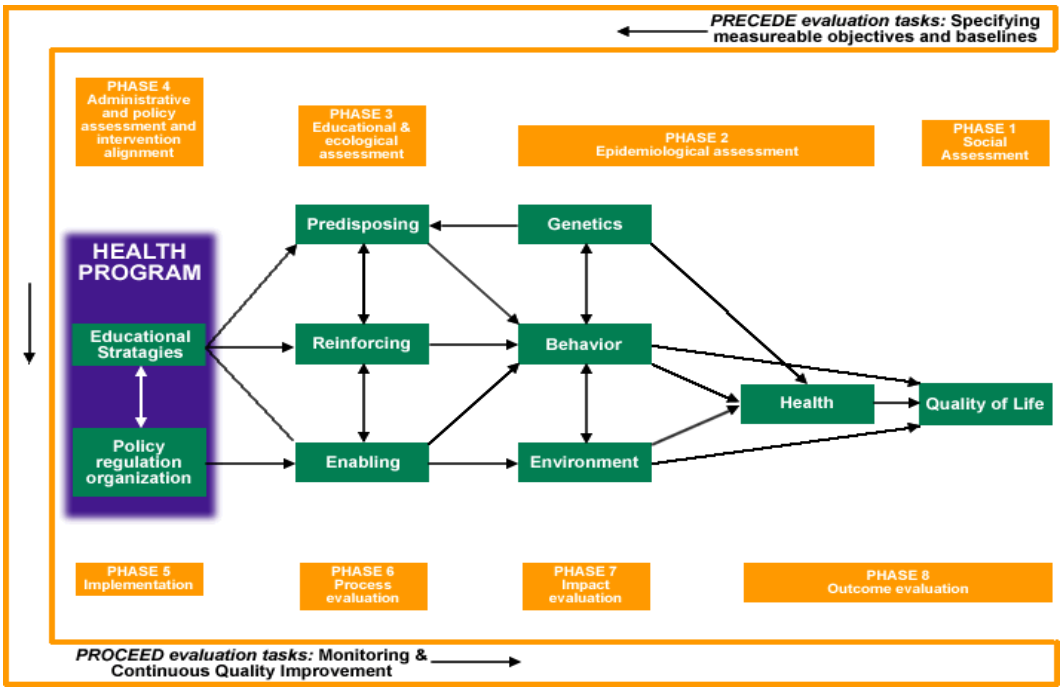

Figure 4: Diagrammatic illustration of the PRECEDE-PROCEED Model (Green & Kreuter, 2005).

However, PROCEED stands Policy, Regulatory, and Organizational Constructs in Educational and Environmental Development. Just as depicted in the name, PRECEDE represents the process that precedes, or leads up to, an intervention, and PROCEED describes how to proceed with the intervention itself after the intervention has been applied.

As illustrated above, both PRECEDE and PROCEED each has four phases **Error! Reference source not found.**). The PP Model is a circular process starting with the quality-of-life survey (on the upper right) and goes counter-clockwise through the four phases of PRECEDE's. Thereafter, PROCEED phases starts, evaluating the success of the intervention. Most importantly, phase 6 evaluation step looks at the success of the intervention in addressing the identified concerns in Phase 3, as planned**Error! Reference source not found.**). In summary, according to Ratz & Lippke, (2021) the phases of PROCEDE aim at:

Phase 1: Identifying the desired health outcome. It could be, for example, reducing the blood sugar level on a consistent basis in diabetic patients.

Phase 2: This is the first level of setting the scene towards identifying the issues, both behavioural and environmental factors that could stand in the way of achieving that result, or those pre-conditions that must be attained to achieve the earlier established desired outcome and results.

Phase 3: Basically, the factors identified in phase 2 could be classified into predisposing, enabling, and reinforcing factors that can affect the behaviours. So, phase 3 deals with classifying these identified factors into their different classes and identify the most expected of the three factors that will influence behaviour, lifestyle, and responses to environment. In this study, we will use these three classifications in the selection (and delimiting) step of the thesis (chapter 3).

Predisposing factors could be viewed as past believes that come from both intellectual and emotional background. The believes tend to make individuals more or less likely to adopt healthful or risky behaviours or lifestyles or to approve of or accept environmental conditions.

Enabling factors are those internal and external conditions are those closely related issues that help people adopt and maintain healthy or unhealthy behaviours and lifestyles, or to embrace or reject environmental conditions (Ratz & Lippke, 2021).

Reinforcing factors, however, are needed to reinforce certain behaviours to support or make difficult adopting healthy behaviours or fostering healthy environmental conditions.

Phase 4: Identifying the administrative and policy factors that influence what can be implemented.

While the four phases of PROCEED emphasises the importance of evaluation, and aim to:

Phase 5: Implementation – the design and actual conducting of the intervention.

Phase 6: Process evaluation.

Phase 7: Impact evaluation.

Phase 8: Outcome evaluation.

In summary, the PRECEDE component of the model allows researcher to work backwards from the desired research goal to create a research methodology to solving the overall aim of the project or intervention. The PROCEED component, however, focuses on the evaluation part of the intervention or project (Binkley & Johnson, 2020).

3 Digital Health and Diabetes Applications

3.1 Pharmaceutical Industry

The world population is expected to reach about 9.7 billion in 2050 from 2.6 billion people in 1950 and 6 billion in 1999. This rapid growth is largely due to the mix of technological advancement, increasing urbanization and accelerating migration ("Population | United Nations," n.d.). Importantly, medical, and pharmaceutical advancements have also played a huge and vital role for the rapid population increase. To this end, the role of the pharmaceutical companies is to develop medications and vaccines to improve the quality of life of people through innovative research to meet the complex healthcare demands of the population; and through the production of innovative medicinal products capable of curing almost all epidemic and chronic diseases ("Pharmaceutical Industry Industry Overview: Trends, Risks, Opportunities & Deals - InvestmentBank.Com," n.d.).

Moreover, this increase in world's population also translates to increased market growth: The global pharmaceuticals market generated 1.3 trillion USD revenue in 2020 and expected to grow at a 3 - 6% compound annual growth rate (CAGR) through the year 2025 to reach a market size of about 1.6 trillion ("Global Medicine Spending and Usage Trends: Outlook to 2025 - IQVIA," n.d.). Furthermore, the global research and development (R&D) spending in the pharmaceutical industry totalled nearly about 200 billion USD ("Global Pharmaceutical R&D Spending 2010-2024 | Statista," n.d.). Most of these recorded revenues have been made on the pharmaceutical industry's traditional business model, which hinges on the ability to identify promising new molecules, test them for efficacy in large clinical trials and market them until they reach a billion dollars sales revenue- a blockbuster status (Pharmaceuticals, Sciences Group Simon Friend, Arlington, Pisani, & Farino, 2020).

Figure 5. The global pharmaceutical industry is expected to grow with an above 5% CAGR growth rate through the year 2025 to reach a market size of about 1.6 trillion. From Global Pharmaceutical Market. Retrieved from https://www.thepharmamarketer.com/post/global-pharmaceutical-market.

This blockbuster business model encourages most pharmaceutical companies to do their R&D through to commercialization alone (Pharmaceuticals, Sciences Group Simon Friend, Arlington, Pisani, & Farino, 2020). However, with several factors like increase in disease incidence, loss of patents, new form of market needs and several ongoing digital innovations, the blockbuster model will not suffice (Pharmaceuticals, Sciences Group Simon Friend, Arlington, Pisani, & Farino, 2020).

On the contrary, a new form of business models will need to be developed which will be based on outcome and result the medicine delivers; and thereby encouraging collaborative cooperation amongst several pharmaceutical companies, academic institutions, hospitals and technology providers, digital health companies etc. In addition, the continuous increase in the global healthcare expenditure and the continuous increase in the disease burden of the developing world closely resembling that of the developed world altogether means a further need for the pharmaceutical companies to adapt to this new reality in their market environment (Pharmaceuticals, Sciences Group Simon Friend, Arlington, Pisani, & Farino, 2020).

Similarly, in addition to some of the factors mentioned earlier dictating the change in the pharmaceutical companies' business model, there are other newly identified trends in the pharmaceutical industry. Some of these trends are:

a. Steady increase in medicine spending and rising prices

According to IQVIA's 2019 Global Medicine Spending and Usage report, there is a steady increase in medicine expenditure in the developed world, and it is projected to exceed 1.4 trillion USD by 2022. This growth is primarily driven by demand in the leading pharmaceutical markets, like China and the United States (Global Medicine Spending and Usage Trends: Outlook to 2025 - IQVIA, 2019). Likewise, the cost of producing new medicine to meet this demand is rising.

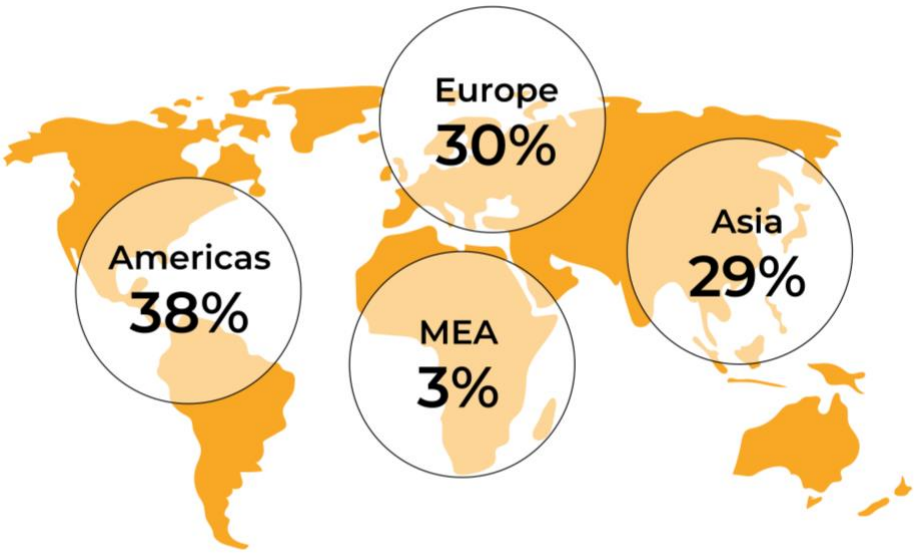

Figure 6. Map of the world illustrating the leading pharmaceutical markets in percentage. From Global Pharmaceutical Market. Retrieved from https://www.thepharmamarketer.com/post/global-pharmaceutical-market.

b. Digitalized medical products or Beyond-the-pill

Beyond-the-pill is the notion behind building and offering complementary services and solutions, especially in digital forms, to diversify the portfolio of the pharmaceutical companies. Like other factors mentioned earlier, the need for pharmaceutical companies to change their business model to build revenue resources is one of the factors influencing this trend (Cattell, Chilukuri, & Knott, n.d.). Moreover, these digitalized complementary products offer cost saving and the means of achieving optimal clinical outcomes, which pills alone cannot achieve; and while still boosting total revenue for the pharmaceutical companies (Cattell, Chilukuri, & Knott, n.d.).

c. Digital Marketing

The notion that pharmaceutical companies are gradually shifting part of their customer interaction to different digital channels is not new, however one of the forces dictating this new digital marketing move is the new product mix being offered in the industry. In addition to the beyond-the-pills products and services offered by the pharmaceutical companies, the

development of protein-based specialist medicinal products is rising (Pharmaceuticals et al., 2020). These products require a new form of marketing strategies, capable of delivering value to the patients and providers. Consequently, it has been observed that because of the deeper scientific basis of most protein-based specialist medicines, scientific educational dissemination of information is needed. Thus, specialist medicines are best promoted via multiple digital channels (Pharmaceuticals et al., 2020).

3.2 Innovation within the Pharmaceutical Industry

Innovation is not a new concept within the pharmaceutical industry. As a matter of fact, the industry is essentially defined by innovation (Ding, Eliashberg, & Stremersch, 2013). The history of innovation in the pharmaceutical industry is made of two periods, with the first period ended around 1930 and defined by the production of alkaloid compounds, vaccines, analgesics, antipyretics etc. The discovery of these broad range of drugs were made possible because of technological advancement within a short time span, constituting a form of radical innovation (Horrobin & Dphil, 2000). In addition, the combination of market demand and radical innovation opened new therapeutic market and new discoveries, with the global innovative productivity, measured as the total worldwide new chemical entity launched by the global pharmaceutical companies every year, reaching around 80 – 100 molecules per year in the 1960s (Horrobin & Dphil, 2000). Furthermore, there were recorded increase in the life span and the quality of human life at an unprecedented level during this period, and it has been on the increase ever since with the advent of modern era medication. All these illustrate and emphasize the foundation of research and innovation that defines the pharmaceutical industry.

However, the industry is not shielded from challenges. Horrobin & Dphil (2000) identified how the innovative productivity has fallen to as low as one new chemical entity per year in some companies. Furthermore, the convergence of the forces of politics, financial and regulatory factors are forcing the players within this industry to re-evaluate their business strategies and find means of increasing the speed of bringing innovative products to market in an efficient and cost-effective manner (Ding, Eliashberg, & Stremersch, 2013). Consequently, research and technological innovation seem like the panacea for most of these challenges. To solve these afore mentioned challenges and drive down cost of drug development, the ongoing trends are in the use of future technologies. Technological trends like 3D- technology, Artificial Intelligence AI, and machine learning, accelerated automation. In response, regulatory authorities are also adapting to be able to meet these changes and trends. For example, in 2015 US Food and Drug

Administration (FDA) approved the first medicine produced using 3-D printing for use in the human body (Reddy, Veeranna, Venkatesh, & Kumar, 2019).

The use of technology in the pharmaceutical industry is expected to bring the much-needed value. However, most technological advancements are prone to make the mistake of focusing on the technological capability of their invention rather than the value it brings to the customers. Therefore, with the myriad use in which digital health products are being currently used in both consumer level products and prescribed digital health medical devices, innovative companies must ensure that their future digital health products not only focus on the innovative idea, but also on how the company manages to exploit their innovative idea to fit market needs and add value to the consumers (O'Sullivan & Dooley, 2008).

3.3 Digital Health and Mobile Health (mHealth)

The future prospect of digital health is huge, and currently the global digital health market Is projected to reach nearly 600 billion USD by 2025. Much of the growth is because of the steady increase in investors' interest that has translated into funding totalling about 21.6 billion USD in 2020, the largest investment amount so far (Cohen, Hung, Weinberg, & Zhu, 2020).

By concept, digital health is a new emerging field that sits at the intersection of healthcare and digital technology. It is important to understand that digital health is an evolutionary result in healthcare practices that transcends technological advancement. This is because digital health is a paradigm shift in thinking and expectations of both healthcare provider and consumers that happened after the maturing of various technologies, such as data analytics, AI and machine learning, robotics, and cloud-based services (Rowlands, 2019). Another common feature of digital health is the ambiguity of its definition. However, the most accurate definition was given from the result of a quantitative analysis which infers that digital health is about the proper use of technology for improving the health and wellbeing of people at individual and population levels (Fatehi, Samadbeik, & Kazemi, 2020). Hence, digital health is about health in a highly digitalized society and the expectations of the consumers in this digitalized society, which is that health services respond to their needs as other services do – digitally, and with the processes of health care organization developed around the life patterns of consumers rather than within the patterns of convenience of health service providers (Rowlands, 2019).

Furthermore, the U.S. Food and Drug Administration identifies the broad scope of digital health to include five major categories, namely: mobile health (m-Health), health information technology (IT), wearable devices, telehealth and telemedicine, and personalized medicine (Perakslis, Stanley, & Brodwin, 2021). Since the scope of this thesis is around digital apps, the literature review will be limited to only one of the major categories of digital health- the mobile health.

Mobile Health (m-Health)

With more than 6 billion mobile phone subscribers, out of which 1 billion are with broadband capabilities, it is estimated that about three-quarter of the world population have access to mobile communication (Becker & Gerhart, 1996). This proliferation of mobile communication devices has played a major influential role in the evolution of m-Health, because with every mobile and internet communications technological breakthrough, it increases global prominence of m-Health (Istepanian & Woodward, 2016). m-Health or mobile health was first coined in 2003, and it implies the use of sensors, mobile devices such as smartphones, tablets, laptops and other communication network infrastructure for health-related applications (Istepanian & Woodward, 2016).

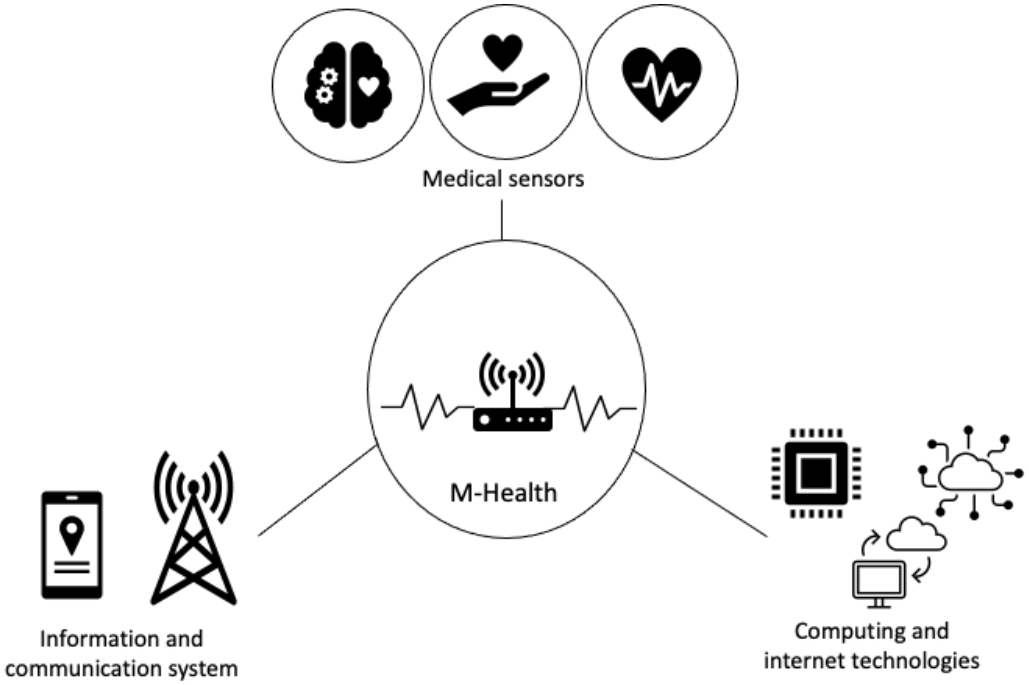

Figure 7. Basic building blocks of m-Health. Adapted from Istepanian & Woodward (2016).

Basically, the concepts that defines m-Health is made up of mobile computing, medical sensors, and computing technologies (Figure 7). This interconnectivity of the three domains represents the foundation to the adoption of m-Health by the future generation because of two reasons, namely: it enables cooperative and faster innovative solutions to healthcare delivery fostered by different perspectives; and provides a platform for constant connectivity or continual digital stimulation through technical evolution in these domains (Istepanian & Woodward, 2016). Hence, it is highly likely that m-Health will be the driver and means of communication between healthcare providers and future generations (Istepanian & Woodward, 2016).

3.4 Overview and the global incidence of diabetes

Diabetes is one of the top 10 cause of death globally, with an estimated 451 million adults living with the disease worldwide in 2017 and projected to increase to about 693 million by 2045, if no preventive methods are adopted (Figure 8) (Glovaci, Fan, & Wong, 2019; Lin et al., 2020). There has been about a 5% increase in premature mortality rates from diabetes, and this contrasts with the 18% global decrease in mortality rate from other non-communicable diseases (NCDs), like cardiovascular diseases, cancer, and chronic respiratory diseases between the years 2000 and 2016 (Lin et al., 2020).

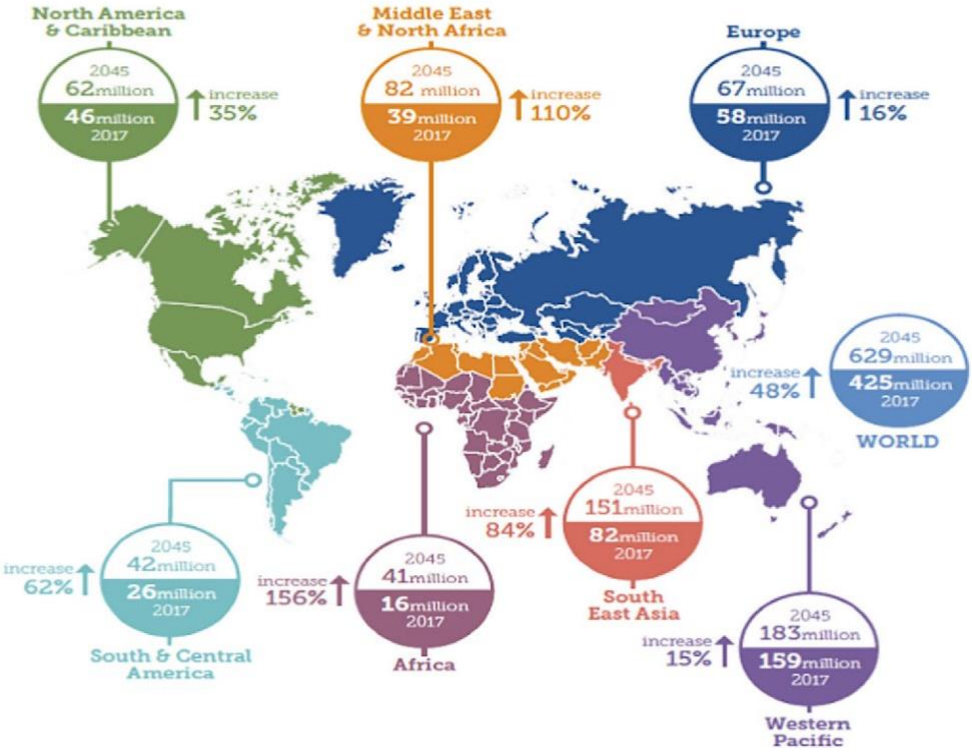

Figure 8. Global incidence of people with diabetes worldwide and per region in 2017 and forecasted for the year 2045 (Glovaci et al., 2019).

Diabetes mellitus is a metabolic disorder caused because of impairment in insulin secretion and/or insulin resistance, thereby affecting the body's capacity to utilize glucose, fat and protein leading to chronic hyperglycaemia (Ojo, 2016). Insulin is a hormone produced by cells in the pancreas called beta cells; and helps the body to breakdown the blood sugar- glucose into molecules of Adenosine Triphosphate ATP (chemical component of energy). However, individuals may be classified as having type 1 diabetes (T1D) if they cannot make insulin or as having type 2 diabetes (T2D) if they can make insulin, but the body doesn't respond well to insulin (commonly referred to as insulin resistance) (Figure 9) (Ojo, 2016).

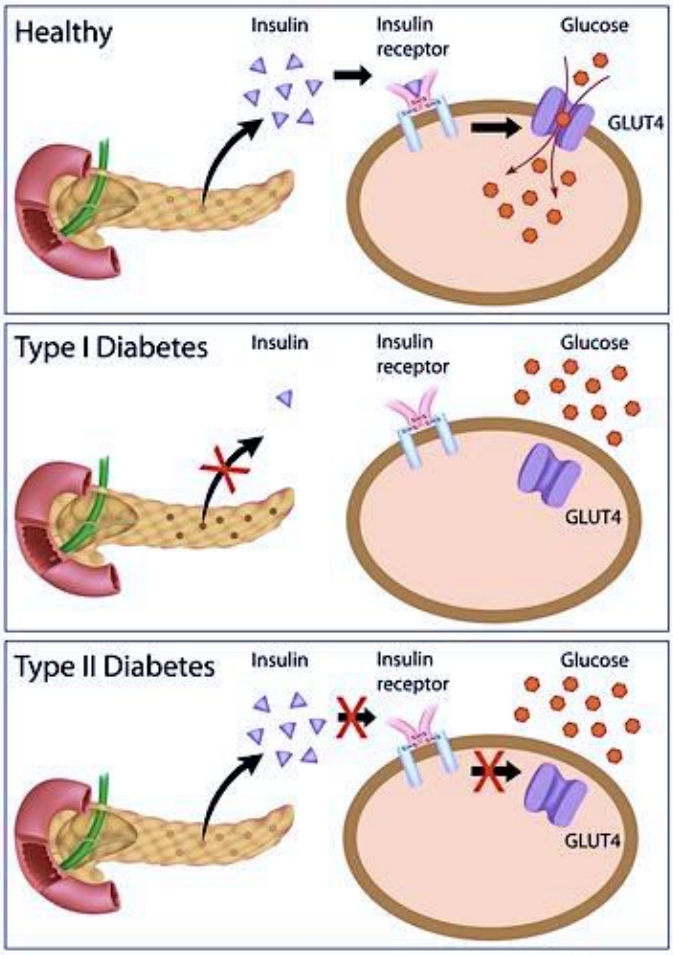

Figure 9. Pictorial illustration of the two forms of diabetes, in comparison to normal condition. Image source: https://beyondtype1.org/my-parents-had-to-learn-the-difference-between-type-1-and-type-2/

From epidemiology view, in T1D, released antibodies destroy the pancreas' beta cells caused often because of an auto-immune reaction. Consequently, the pancreas fails to produce enough insulin to bind to the glucose and this leads to an increase in the blood sugar. In T2D however, the liver cells become insulin resistant causing reduced absorption of glucose into the

bloodstream. In response to this high glucose presence in the blood stream, the pancreas overproduces more insulin but with the liver's inability to absorb the glucose, it results in an increase in the blood sugar (Eyth, Basit, & Smith, 2022). The diagnostic criteria for patients with diabetes are fasting plasma glucose ≥7.0 mmol/L and oral glucose tolerance Test (OGTT) ≥11.1 mmols/L (Ojo, 2016).

3.5 Current landscape of diabetes apps

Diabetes remains one of the most expensive diseases; with its prevention and management market valued at about 11 billion USD and poised to grow at a 6.8% growth rate over the period of 2020-2026 ("Blood Glucose Monitoring Systems Market Research Growth by Manufacturers, Regions, Type and Application, Forecast Analysis to 2026 - MarketWatch," n.d.). Furthermore, diabetes prevention and self-management is a highly demanding responsibility despite empirical evidence correlating it towards improving quality of life and preventing complications and premature mortality (Kebede & Pischke, 2019). Kebede & Pischke (2019) further suggests that there are several benefits with the use of diabetes mobile applications (DM apps) for the management of diabetes, namely:

a. Advancing their disease knowledge, awareness of possible complications and their personal self-management

b. Improvement in controlling their glucose level and ability to accurately monitor their physical activity and nutrition

c. A more convenient digital platform for patients to monitor their progress towards achieving their personal glycaemic and behavioural goals

Furthermore, DM apps can be classified based on technical design and based on the diabetes self-management tasks it focuses on, such as blood glucose monitoring, medication or insulin dosing diabetes education, nutrition and physical activities tracking. As such, the diabetes digital apps are categorized based on both functionality and the market development phase (Alexander Fleming et al., 2020; Research2guidance, n.d.) (Figure 10).

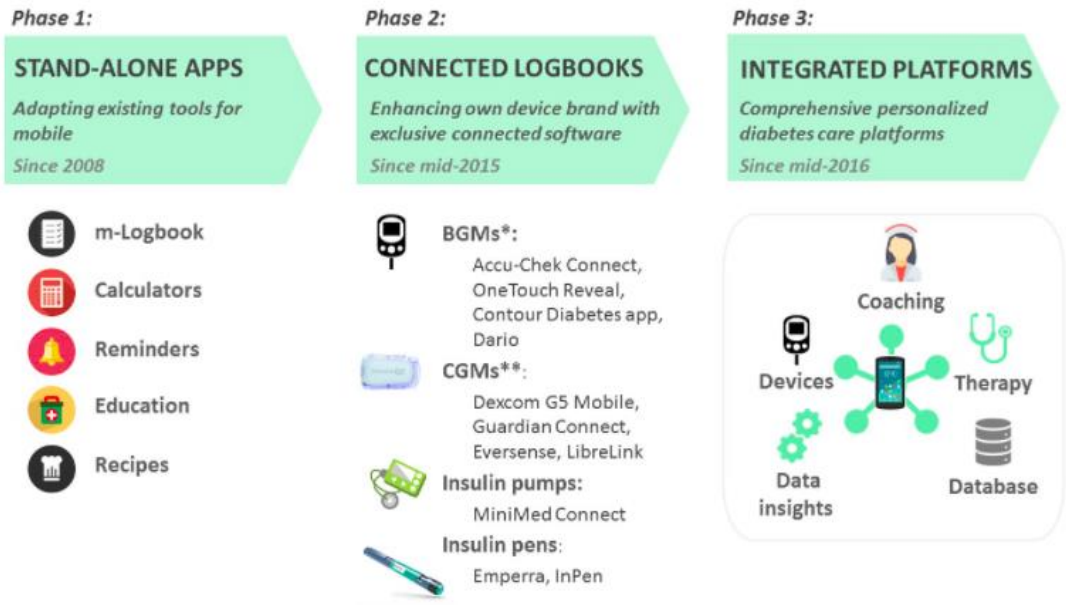

Figure 10: Current landscape of diabetes apps. From The 3 phases of the diabetes app market development. Retrieved from https://research2guidance.com/the-diabetes-app-market-development/.

3.6 Behavioural change and theories in diabetes apps design

At its core, diabetes is a behavioural challenge as the management of the disease requires both the initiation and maintenance of a series of complex behaviour of both the person with diabetes and their healthcare professionals. Thus, behaviour change is central to the effective management of diabetes (Mcsharry et al., 2020). This school of thought is also supported and well summarized by Gale in 2004, who noted: 'The evidence that behaviour is the dominant element in successful management of diabetes is so overwhelming that we tend to ignore it' (p. 439 – 449).

Human behaviour refers to both physical and emotional activities that describes the 'what', 'when' and 'why' of human's daily happenings (Klonoff, Kerr, & Mulvaney, 2020). However, health behaviour are behaviour patterns, habits and actions that relates to all the aspects of health maintenance, restoration, and improvement with the capacity to impact individual's health positively or negatively (McSharry et al., 2020). Consequently, behavioural theories help shed light on human behaviour, and help researchers understand why individuals engage or do not engage in certain activities (Klonoff et al., 2020). With regards to diabetes, some of the health behaviour might include eating healthy, self-monitoring of blood glucose level, taking medication as prescribed, engaging in daily activities etc. Furthermore, empirical studies also show the importance of leading an active lifestyle in the management of diabetes. Moreover, the use of

diabetes technologies like digital apps can help with health behaviour changes and help with the treatment of diabetes patients; and prevent diabetes in healthy people (Fadhil & Wang, 2019).

With advances in diabetes technologies, health behavioural change theories can optimize self-management and care of individuals with diabetes (Klonoff et al., 2020). Thus, incorporating behavioural theories in the development and evaluation of diabetes technologies offer a unifying framework to identify the key determinants of health behaviour change, like how individuals engage with the technology, and make health decisions (Klonoff et al., 2020). Some of the four common theories that have been applied in diabetes research with elements of behavioural change are: Social cognitive Theory (SCT), the Health Belief Model (HBM), PRECEDE-PROCEED model, and the Information-Motivation-Behavioural skills (IMB) model (Klonoff et al., 2020; Weir, Mcleskey, Brunker, Brooks, & Supiano, 2011). The PRECEDE-PROCEED model will be used as part of the content analysis step in chapter 2 of the thesis.

3.7 The Needs of Diabetic Patients

From the business perspective, understanding the needs and associated emotions, such as fear of the target customers, are necessary blueprints in adding values to any business' products or service offerings developed or being developed (Smith & Colgate, 2007). In addition, it also allows businesses an empirical basis for future improvement of their initial offered products and services to these needs and fears.

For diabetic patients, the identified fears are like any fear associated with any disease; and sometimes are different based on the stage of the disease diagnosis. This varies from patient's acceptance of the disease in the early stages and the gradual familiarization with the treatment (Papaspurou et al., 2015). As such, according to Papaspurou et al. (2015) the associated fears identified in diabetic patients are:

a) Early stages (After diagnosis) fears, which includes fear for life and complications from the disease, fear for the future, fear for their family susceptibility to the disease because of genetics

b) Fears associated with gradual familiarization include mainly the fear of stigmatization

However, studies have associated the continuous increase in the economic cost of managing diabetes to the lack of complete understanding of the needs of diabetic patients (Association, 2013). The key needs of diabetic patients are (Papaspurou et al., 2015):

a) Need for Psychological Support and Self-Management Education

Psychological support for diabetic patients is one of the most important needs, as evident from the various online and offline support groups, which are now very common. Aside psychological support offered by these groups, the other objectives are to form communities around the disease and condition to give the patients a sense of belonging and the feeling of 'not alone'. The other advantage is the ability to share experience and self-management practises with people with similar condition, outside the regular prescription of the healthcare practitioner.

b) Need for awareness about behavioural change and medication

While medication is vital for the management of diabetes, the core better outcome for diabetic patients' management is awareness and incorporating certain activities as part of their treatment that can initiate healthy behaviour change.

c) Need for knowledge about hypoglycaemia and other related complications

d) Need for communication and where to get help

The above list of needs of diabetic patients are indication of the associated complications and effects that every chronic diseases have in the lives of the patients.

4 Methods and Research Strategy

Diabetes mellitus (DM) is one of the top 10 causes of death globally and empirical evidence shows that there are several benefits with the use of mobile digital apps for the management of diabetes. There are already growing adoption on the use of DM-specific mHealth apps for the management of diabetes, with more than 46.3 million app installations in 2019, which represented approximately 11% of patients with DM diagnoses worldwide in 2019.

Many studies have already focused on the clinical effectiveness of these DM-specific mHealth apps. However, there are still gaps in the evaluation of the market performance of these apps. Therefore, the overall aims of this thesis are to validate the selected diabetes digital apps to see if they satisfy the needs of its targeted patients; and analyse the market performance of these selected diabetes apps. To achieve these aims, an abductive approach and an embedded multi-case study strategy was employed.

4.1 Abductive Approach

Generally, an abductive approach to research starts with an incomplete or non-specific observations and attempts to establish a new theory, following a pragmatist perspective (Mitchell, 2018). Thus, researchers using this approach begins with an empirical phenomenon that the present theories cannot justifiably and accurately explain. Thus, data will be collected and used to explore this phenomenon, identify patterns, and then moves towards formulating a suitable proposition/theory from the inference of the data. Based on the present gaps within the empirical theories describing and validating the quality of diabetes and mobile apps, research questions and objectives that aim to elucidate the market performance and validity of the available diabetes mobile apps were formulated. Consequently, through data collection these formulated aims and research questions will be answered.

4.2 Multi-Case Study: Justification and Rationale

Case study is a research strategy used when there is a need for an in-depth and multi-faceted understanding of an issue in its real-life context (Crowe et al., 2011). In other words, case study is used when there is a need to explore a phenomenon in depth and in its natural context, without

element of manipulation of the research variable(s). Case study addresses research questions that are descriptive or explanatory in nature often with - 'How or why did something happen?' Relating it to this research work, the formulated research questions this proposed research project hopes to answer approaches with the 'how' and 'why' questions, and thus justifies the reason for its choice as the research strategy. Furthermore, case study has now become the most reliable research strategy for evaluation and qualification research, as done by a lot of health authorities for example U.S Food and Drug Administration (A (Very) Brief Refresher on the Case Study Method, n.d.).

Another feature of a case study is the number of cases the research is trying to answer- either as a single case or multiple cases. There is also the possibility to define the context onto which the case is being studied, either as holistic or embedded. The embedded nature of this proposed research study refers to the two selected DM apps that represent the units of analysis of the case, and the multi-case design reflects the different contexts to be studied, namely patients' need satisfaction and digital market performance (Figure 11).

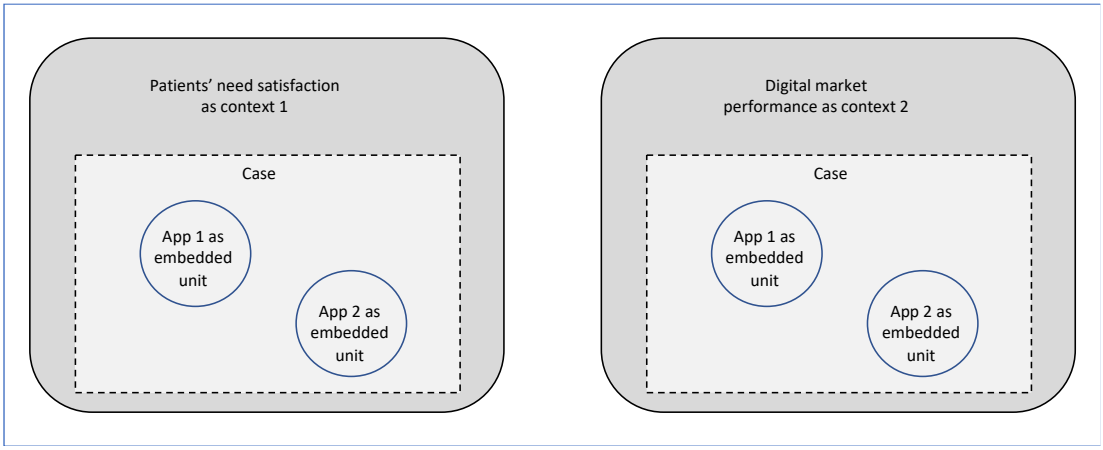

Figure 11. The embedded multi-case study illustration of the proposed research work. The embedded nature of this proposed research study refers to the two selected DM apps that represent the units of analysis of the case, and the multi-case design reflects the different contexts to be studied, namely patients' need satisfaction and digital market performance. Adapted from (*A (Very) Brief Refresher on the Case Study Method*, n.d.).

4.3 Mixed Method for Data Collection and Analysis

Mixed method approach to data collection and analysis refers to the application of both qualitative and quantitative data collection methods and analysis (Saunders et al., 2009). The

implication is a final data set of precise and meaningful information for analysis. The present study was conducted using mixed method. Quantitative data was collected using questionnaire that was administered to an independent app developer and triangulated with qualitative data collected from reviews and description of the selected apps.

4.4 Research Design

4.4.1 Sample

Samples included in this study came from three app stores namely, SlideME, Google Play Store and Apple app store. The samples were selected from the diabetes and health section by using the search term 'diabetes and health'. Data was scrapped using the software Octoparse https://www.octoparse.com.

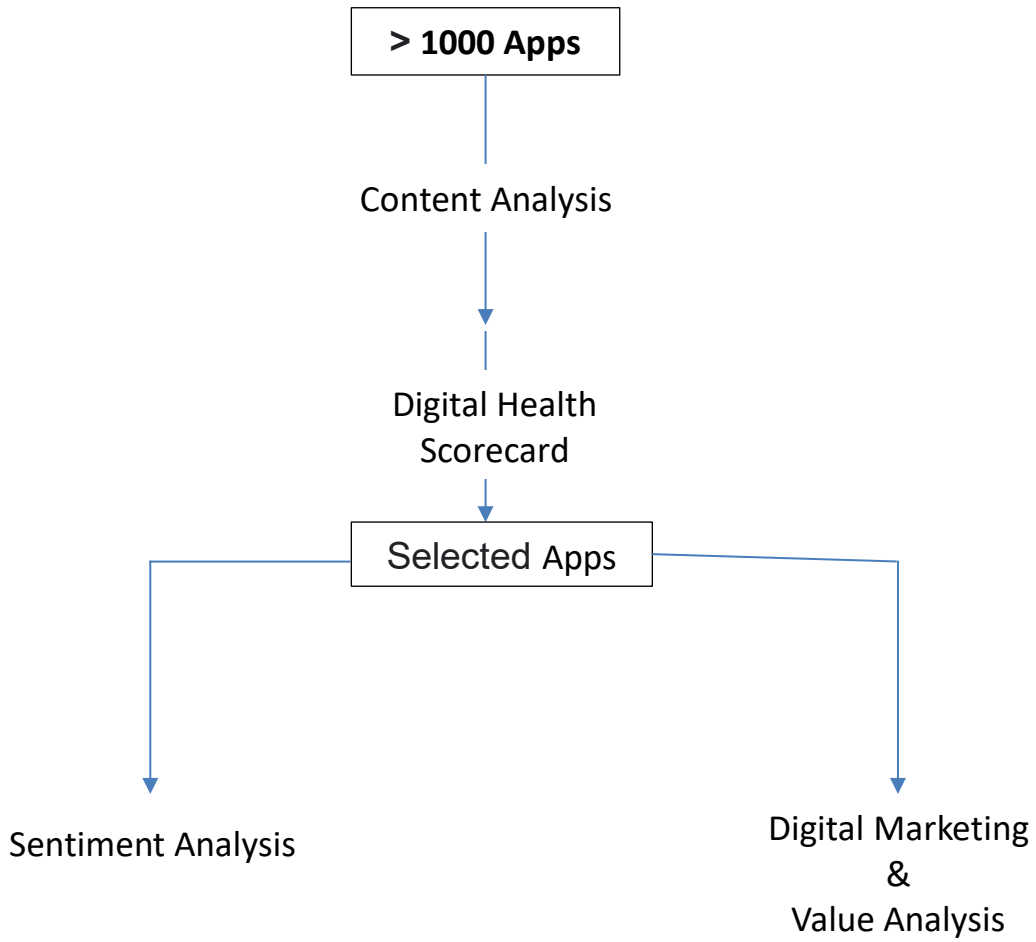

Figure 12. Schematic representation of the research methods.

4.4.2 Apps Selection

The final apps selection involved three selection steps (Figure 12 and Supplementary 1), comprising of:

a. Manual Cleaning

The samples were downloaded in Excel format and reviewed manually removing samples that met the following criteria:

- That do not have anything related to diabetes and health included in their descriptions
- Are not apps (e.g., diabetes recipe book)
- Sample name and description in any other language aside English language

b. Content Analysis

Using PPM

The PPM was used to code each of the app following the three levels of the anticipated influence and health behaviour determinants of the model. As defined and used in other similar research works, the three main categories used in this study follows according to the PPM model, which includes: predisposing factors, enabling factors, and reinforcing factors.

Table 2. A table showing the PPM categories used in the classification of the downloaded apps.

		Theoretical PPM factors for classification		
Developers name	App's description	Predisposing factors	Enabling factors	Reinforcing factors

The following definitions of the three categories of the PPM model was used for the coding according to West et al., (2012): Predisposing apps focus was on cognitive- or affective-based factors, and usually precede one or more targeted behaviours. Moreover, predisposing apps are knowledge and awareness of conditions or outcomes oriented (e.g., an app that provides cancer statistics); providing information (e.g., an app that presents information regarding ways to prevent adverse health outcomes); discusses beliefs, values, or attitudes (e.g., an app that discusses common reasons to avoid tobacco in an effort to assist the user in quitting smoking);

and inspires confidence or motivation (e.g., an app that tries to convince you that you can change your diet) (West et al., 2012).

Enabling coded apps are those apps targeted to be used at or around the same time as the desired behaviour and they enforce a new behaviour formation through teaching a skill (e.g., an app with pictures and instructions on healthy stretching), providing a service (e.g., an app that geo-locates places for physical activity), or tracking progress/recording behaviour (e.g., calorie counter apps). Lastly, reinforcing apps are reward and feed-back from others following adoption of a behaviour, which often can be either an encouragement or discouragement of the continuation of a behaviour. Besides, apps are reinforcing if they provide a connection with a social networking site (e.g., apps with automatic upload to Facebook), provided encouragement from trainers/coaches (e.g., an app that featured easy communication with a coach or trainer), and included an evaluation based upon the user's self-monitoring (e.g., an app that provided automated feedback about user's reports of his/her physical activity) (West et al., 2012). Thus, the app developer's description and the relevant websites of the app developers were checked to see evidence of any of the PPM categories.

In addition, as most diabetes app can be classified into different categories based on focus, i.e., blood glucose level tracking, diabetes recipe, diabetes exercise and workout, there were no distinction (regarding categorization of diabetes app based on focus) made during the selection step. Consequently, all apps were considered in the selection step regardless of the categories (Supplementary 2).

c. Digital Health Scoreboard

The second step in the selection step using the Digital Health Scorecard framework was performed on the resulting apps from the first selection step involving PPM. This selection method is as described by Simon et al., (2019) and as done by (Sedhom et al., 2021), with some adaptation. Simon et al. (2019) described the digital health scoreboard to encompass four domains evaluation, namely: technical, clinical, cost, usability, and end-user requirement. For this analysis, cost was exempted, and end-user requirement was adjusted to focus more on the needs of diabetic patients. The domain areas of technical, usability and diabetic patients' needs were evaluated using interview methods, which were delivered as questionnaires (Appendix 1) from 21 April 2022 to 29 April 2022 to an independent app developer freelancer with training at university degree level in app development and software engineering. To perform these domains evaluation, each app was downloaded by the freelancer and evaluated against the 20 interview questions, which covers these three domains. In addition, the clinical domain was adapted,

evaluated, and administered as interview questions. The interview questions focus on establishing the medical experience of the app developer/team and any evidence from peer-review research papers to support the medical and clinical relevance of the app. This part of the evaluation was performed by the researcher of the project, because of his scientific and medical background.

4.4.3 Scoring and Final Apps Selection

To select the final sets of diabetic apps for further analysis, the aggregate score for all evaluated domains as defined in the Digital health scoreboard selection step was first computed. The aggregate score for each app is computed as a summation of all possible points based on the response value as assigned in the interview questions. For example, technical domain (with focus on security, privacy, interoperability, performance, visual design & readability, app navigation, notifications, help & support, content & personalization) has an aggregate score of 23, end-user requirement (14), and clinical evaluation (6) (Appendix 1). Thereafter, a domain cross-referencing was done between the clinical and technical domains such that all apps with a clinical domain aggregate score greater or equal to one were cross-referenced with apps that were identified and scored for technical domain validation. However, there were some apps that had technical issues either with regards to accessibility and/or app crashing during evaluation by the freelancer. For example, ApolloSugar – Healthcoach has accessibility restriction. Consequently, such apps were removed from further analysis. ANOVA statistical test was done to test the level of significance of inter-app variation using PSPP. At the end of the selection steps, a total of nine apps were left for further analysis.

4.4.4 Analysis

To answer the three research questions of the research work, both sentiment analysis and digital market productivity/performance analysis was done using user reviews.

Web-scraping: Reviews

User reviews of the nine selected diabetes apps were scraped from Google Play Store using Outscrapper (https://outscraper.com/).

Analysis 1: Sentiment Analysis

Natural language processing involves analysing large data sets of natural language, and often used in business analysis and consumer behaviour (Meyer and Okuboyejo, 2021). Sentiment analysis is a subset of natural language processing that analyses the thoughts, emotional reactions, and feelings regarding a topic and classify these thoughts/feelings as positive or negative. In this study, sentiment analysis was performed on the extracted reviews of the nine selected diabetes apps using the MeaningCloud (https://www.meaningcloud.com/). The expected classification is that the algorithm will return six possible levels of polarity, namely P (positive), N (negative), P+ (very positive), N+ (very negative), Neutral and None (no polarity is detected). The pre-processing of the data was manually done by copying the extracted review from the web scarping program as csv data to Google spreadsheet, which has the API from MeaningCloud included as add-on.

Furthermore, apps with review number lesser than five were exempted from sentiment analysis. However, only the apps with more than 300 reviews were used for further analysis related to answering the research question 1.

Analysis 2: Digital Marketing Productivity Metrics

In order to evaluate the performance analysis and brand perception of the selected apps, some of the already explained metrics in section 2.2 were calculated:

a. Brand Awareness

In earlier studies, most brand awareness measurement has been done using survey-based questionnaires, which asks respondents to answer a variety of awareness questions about a brand. However, there is a growing difficulty in obtaining response to these surveys, as users/customers (targeted respondents) are becoming increasingly unwilling to answer these surveys. At the same time, with the ability of digital platforms to track customer/user behaviour it presents an opportunity to gather data easily and at a much lower cost (Dotson, Fan, Feit, Oldham, & Yeh, 2017).

The Google Trend is a useful digital tool used to measure popularity of a search query over time; and it observes trend and global/regional variations of the query over time. Thus, it analyses the internet and identifies the specified name or phrase over time, hence its perfect use in brand awareness measurement. To obtain the value for Aware, each of the name of the selected app was used as the search term in Google Trend (http://www.google.com/trends), using the search time range as recorded from the sentiment analysis. Aware value corresponds to the number of

individuals that recognize and know a brand; and it is used in the calculation of Purchase Action Ratio, Brand Advocacy ratio below.

b. Purchase Action Ratio (PAR)

PAR = Act / Aware

PAR is a measurement of how well a brand converts people who are aware of it to act, either in form of downloading or purchasing it (Kartajaya et al., 2016; Kotler et al., 2020). For this research, the action considered as an 'Act' is the downloading of the selected apps by users, and who left reviews. So therefore, the total number of all users that acted by downloading the selected apps were those users, who left reviews (either positive or negative reviews) that was used for sentiment analysis.

The value of the variable 'Aware' was obtained as specified above, which is the number of times people have searched the app's name using Google Trend.

c. Brand Advocacy Ratio (BAR)

BAR = Advocate / Aware

BAR is the percentage of people in the market who spontaneously remembers a brand and recommends it to others (Kartajaya et al., 2016; Kotler et al., 2020). It is the measure of how well a brand converts people who are aware of it into a loyal advocator (Sugiyanto & Wicaksono, 2020). In essence, BAR is equivalent to the measure of loyalty.

To calculate the number of users, who are willing to advocate on behalf of the selected apps, we used the extracted reviews with positive polarity. The reviews were first filtered for positive and + positive sentiments polarity. Then, the reviews were further filtered for words specifying advocacy, like 'recommend' and 'buy'.

The value of the variable 'Aware' was obtained as specified above, which is the number of times people have searched the app's name using Google Trend.

d. Net Sentiment Score (NS)

The real-time analysis of unstructured opinion about a brand, particularly understanding the real-time reason behind the loyalty for a brand, can be done using the Net Sentiment Score. (Ahmad, Chandra, & Tyagi, 2019; Lewis & Mehmet, 2019) gave the formular for NS in their research work as:

$$\text{NS} = \frac{\%\text{ of Positive Mentions} - \%\text{ of Negative Mentions}}{\%\text{ of Total Mentions}}$$

Analysis 3: Value Analysis

In business, value creation lies at the centre of all strategy and becomes the most important factor in the conferring a competitive advantage to a business.

In this part of the research, the intended value created by the selected apps was analysed using the value proposition canvas. The overall goal is to demonstrate either of the two levels of fit, i.e., Problem –to– Solution Fit or Product –to– Market Fit (Figure 13) (Osterwalder et al., 2014); and this directly answers the research questions 2 and 3.

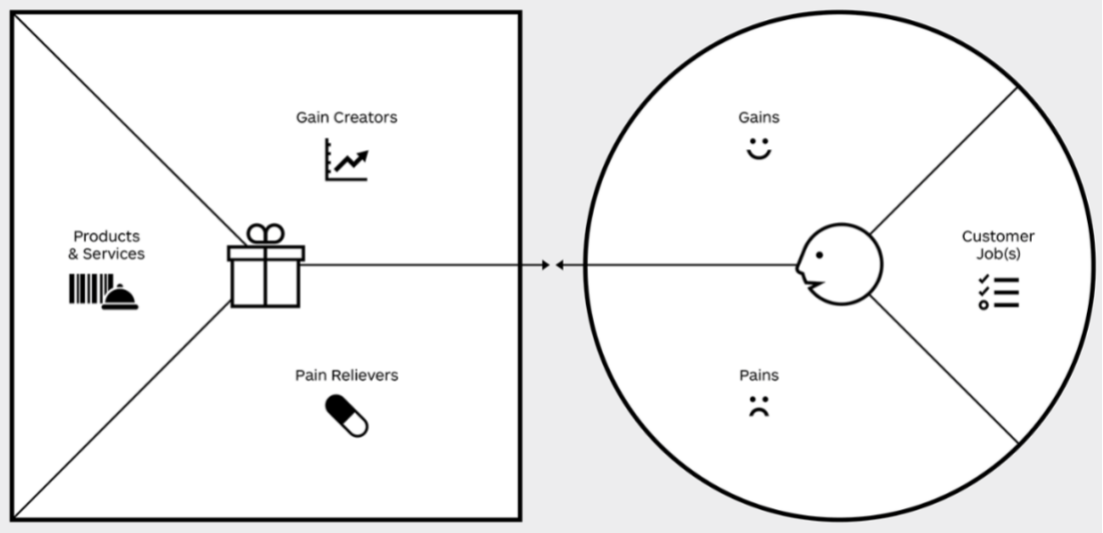

Figure 13: The value proposition canvas as proposed by Osterwalder et al., 2014.

The value analysis focused on the customer side of the value proposition canvas, which comprises of the Customer Jobs, Gains and Pains. To analyse the jobs the customer wanted completed, a word cloud was built using an Excel Add-on software ChartExpo using verbs from the users' reviews, which were downloaded for the sentiment analysis (Analysis 1). These words were of neutral sentiment polarity and have more than 10 number of occurrences. The rationale behind a word cloud is to identify the action words with neutral sentiment, which identifies technical functionality.

For the other two parts of the customer side of the value proposition canvas- Gains and Pains, adjectives, and verbs from users' reviews with positive and negative polarities were used

respectively. The rationale behind choosing adjectives is to identify the descriptive and action words that compares and describes the emotions expressed in the reviews, as already identified with the sentiment polarities. Thereafter, a co-occurrence analysis was performed using KH Coder (http://khcoder.net/en/). KH Coder uses Jaccard coefficient to calculate the strength of co-occurrence. Co-occurrence is a visual representation of a sematic network analysis that is used to illustrate relationship between words in a text.

The above method of value analysis used in this research was already done by (Pokorná, Pilař, Balcarová, & Sergeeva, 2015), but with modification.

To complete the value analysis, a value proposition comparison between the two selected apps- Carb Manager and Glucose Buddy diabetes tracker was done, comprising:

a. Domain Comparison Bar Chart

Since every business is in the market to provide value through their product or service offered, a market fit between the offered service or product is essential. To compare the product –to-market fit between the selected apps, a domain comparison bar chart was built with an Excel Add-on software ChartExpo, using the data from digital health score card (section 5.4.2c).

b. Sentiment comparison chart

In addition, the Problem –to– Solution Fit was compared between the selected apps by a sentiment comparison chart, using reviews of both positive and negative polarities from year 2018 to 2022.

5 Results

There is a rapid proliferation of mobile health apps and in response is the associated models for evaluating the clinical validity of the apps. However, there is still a gap in the analysis of the performance of the different digital marketing strategies employed by most of these apps. This among other research questions is what the research work will answer.

5.1 About the Commissioner- Bridgeocean Limited

Bridgeocean Limited www.bridgeocean.digital was incorporated in 2021, with a subsidiary in Ireland. As a young start-up, most of the operational frameworks are still at infancy. Nevertheless, the mission of the company is to bridge operations in healthcare using technology; and with B2B as her mode of operation. Moreover, one of the areas of focus of Bridgeocean is in digital health and digital marketing. The business focus is because of the proliferation of mobile apps in the healthcare space, and the urgent need to validate their usefulness in this space.

Present Situation

The first target product of Bridgeocean Limited is a digital platform with the capability of self-validation of mobile health apps. To achieve this, a framework is needed. However, the present situation is that there are no theoretical plan and framework on to which this desired digital product can be built. Thus, the commissioner hopes with this research to:

a. Develop a framework incorporating both the heath behavioural change and digital marketing performance models.

b. Assess the usefulness of such framework on the validity of already-in-the-market mobile apps.

At the end of the research work, the developed framework will be the basis on which Bridgeocean Limited will further build upon towards developing the digital platform.

5.2 Selection and App Categorization

Our analysis started with a total of 1100 apps as sample size and after manual cleaning, we were left with a total of 196 apps for content analysis using PPM. Out of the PPM coded 196 apps, most were coded as enabling at 70.4% (138/196) and followed as predisposing at 57.1% (112/196) (Table 3). 39.3% (77/196) of apps were coded as reinforcing and 18.9% (37/196) apps were coded to include all the three PPM levels. These 37 apps coded to include the three PPM levels were passed through further level 2 selection process, using digital health scorecard.

Table 3: 196 apps were left after the categorization step using Proceed-Proceed Model (PPM) selection process. The identified app number per the PPM level indicates apps that might be identified in a single level or more than one level. Moreover, apps in all three levels are separated and indicated at 37 (18.9%).

PPM Level	App number (%)
Predisposing	112 (57.1)
Enabling	138 (70.4)
Reinforcing	77 (39.3)
All three levels	37 (18.9)

Further level 2 selection method involves the use of the digital health scorecard as described in the method section (chapter 2). The digital scorecard selection criteria used in this research work is an adaptation as described by Simone et al. 2019, with technical, clinical, usability and end-user requirement as the chosen domains of focus.

Across the three domains analysed, the maximum percentage score of the selected apps is above 80%, with the highest percentage maximum score recorded in the clinical domain (Figure 14 and Figure 15).

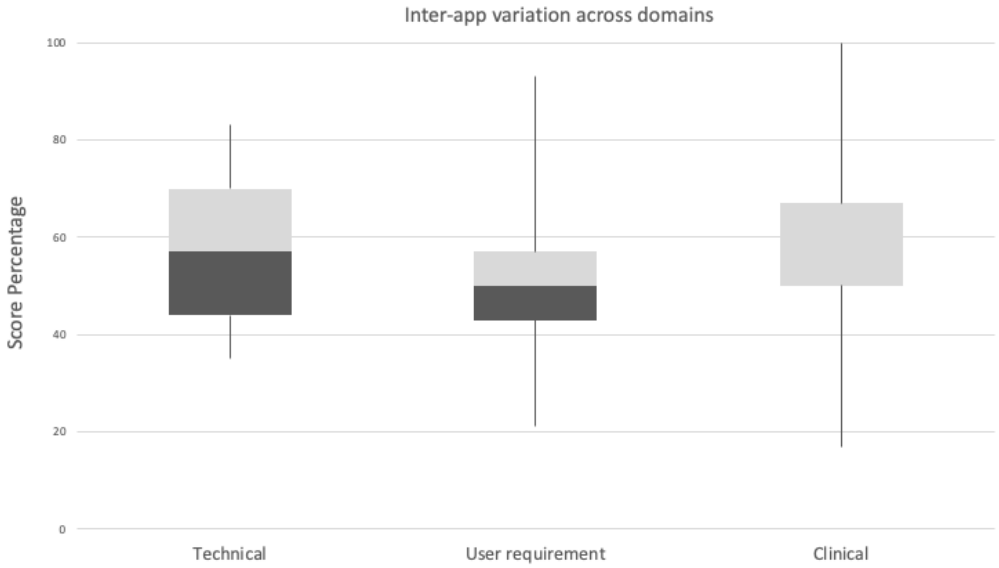

Figure 14: Inter-app variation across the three domains represented as a box plot. All the median percentage score are over 50%. The black and grey box represent the percentage score distance between the lower quartile and median, and the median to the upper quartile respectively. In the clinical domain, the lower quartile is the same value as the median.

Furthermore, the minimum average percentage score within the clinical domain recorded across the apps is lower compared to the recorded percentage score value in other domains. Moreover, the lower percentile range score is equal to the median score (Figure 15).

There was considerable inter-app variation across domains, however this difference is not statistically significant (Figure 15) (

Table 4).

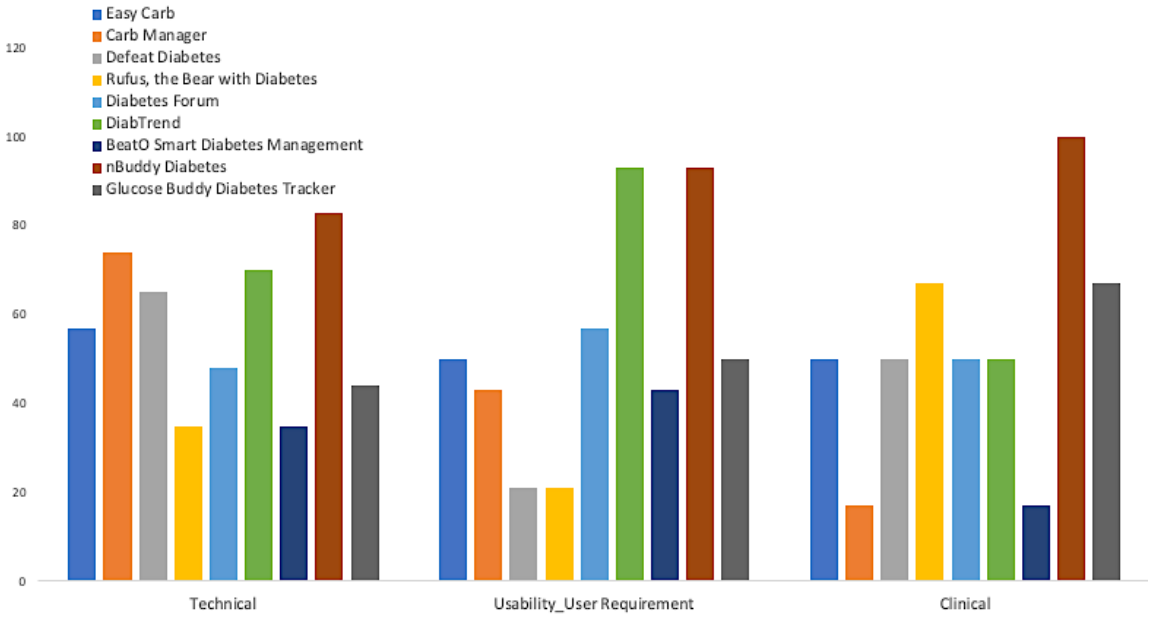

Figure 15: A bar chart showing the PPM selected nine apps analysed within three domains, namely Technical, Usability, and Clinical.

All analysed apps performed best in the domain of technical with the average percentage score of 57%. And the other two analysed domains- usability-user requirement and clinical were of lower and of equal percentage score at 52%.

Table 4: Inter-domain performance score statistical test using ANOVA

	Degree of Freedom	Sum of Squares	Mean of Square	F-stat	P-Value
Between groups	2	128.0761	64.0381	0.1172	0.8899
Within Groups	24	13113.5386	546.3974		
Total	26	13241.6147			

The aim of the usability-user requirement domain is to answer the research question if the needs of the diabetes patients were met in the design of the mobile diabetic apps. The three analysed diabetes apps Diabetes Forum, DiabTrend and nBuddy Diabetes scored higher in this domain, while the Carb Manager, Defeat Diabetes, Rufus, the Bear with Diabetes, BeatO Smart Diabetes Management scored lower (Figure 15).

Out of nine apps for sentiment analysis, two apps were without reviews and three apps had less than 100 reviews, and these five apps were therefore removed from further analysis. The basis for the selection of apps with 100 reviews or more is based on the requirements of the software used for sentiment analysis. At the end, four apps, Carb Manager, Diabetes Forum, BeatO Smart

Diabetes Management, Glucose Buddy Diabetes Tracker, have more than 100 reviews. Out of these four apps, only two apps- Glucose Buddy Diabetes and Carb Manager have more than 500 reviews, which were used for sentiment and digital marketing and value performance analysis. The two apps were selected because of the sample size in terms of review numbers and as described by Meyer and Okuboyejo (2021).

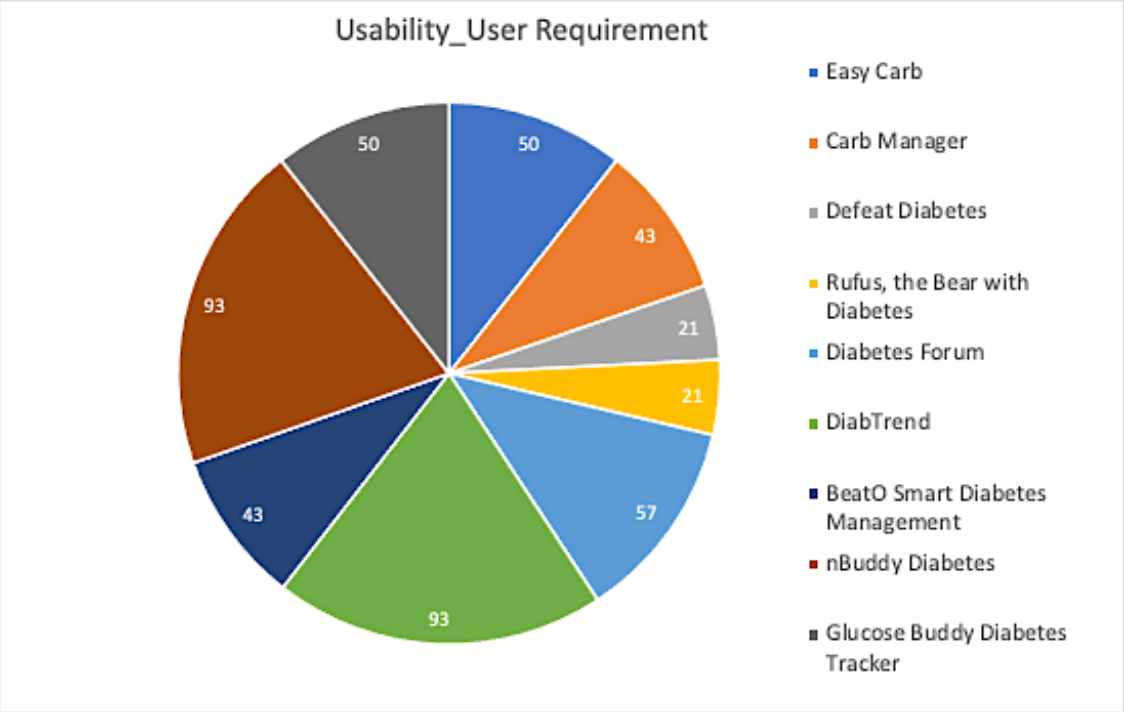

Figure 16: The need of the patient is part of the user requirement specification that is expected to be designed into the mobile app. As part of the selection step, each apps were analysed per the selected domains, as represented in the pie chart.

5.3 Sentiment Analysis

The sentiment analysis of the two apps with more than 500 reviews is summarized in (For Glucose Buddy Diabetes tracker app, about 1000 reviews were recorded and used for sentiment analysis (**Error! Not a valid bookmark self-reference.**). In general, the positive polarity is divided into two polarities- positive and very positive, while the negative polarity is also classified into negative and very negative polarity.

Out of the 1000 reviews, about 539 (54.1%) reviews were categorized to have a positive polarity (Table 5).

Table 5) and (**Error! Reference source not found.**). Furthermore, the results of the sentiment analysis of the remaining five apps, with lesser than 500 reviews, can be found in Appendix 2 - 6.

For Glucose Buddy Diabetes tracker app, about 1000 reviews were recorded and used for sentiment analysis (**Error! Not a valid bookmark self-reference.**). In general, the positive polarity is divided into two polarities- positive and very positive, while the negative polarity is also classified into negative and very negative polarity.

Out of the 1000 reviews, about 539 (54.1%) reviews were categorized to have a positive polarity (**Error! Not a valid bookmark self-reference.**).

Table 5: Sentiment analysis of a diabetes app 'Glucose Buddy Diabetes' using reviews from year 2012 to 2022. Sentiment analysis sentiment analysis was performed using the MeaningCloud https://www.meaningcloud.com/. The expected classification is six possible levels of polarity, namely P (positive), N (negative), P+ (very positive), N+ (very negative), Neu (Neutral) and None (no polarity is detected).

Date	None	P+	P	Neu	N	N+	Total
2012	1	3	22	4	6	0	36
2013	2	15	95	15	10	0	137
2014	5	24	119	32	29	4	213
2015	4	20	103	26	20	1	174
2016	4	11	48	6	11	1	81
2017	3	16	49	20	28	7	123
2018	8	8	30	13	22	2	83
2019	2	6	16	4	7	0	35
2020	6	7	28	6	10	0	57
2021	5	7	21	4	8	0	45
2022	1	0	8	3	0	1	13
Total	41	117	539	133	151	16	997
Mean	3.7	10.6	49.0	12.1	13.7	1.5	90.6
%	4.1	11.7	54.1	13.3	15.1	1.6	100.0

Furthermore, within this positive category the highest total number of positive reviews were recorded in the years 2014 and 2015, at 119 and 103 positive reviews respectively. This is an equivalent of 55.9% and 59.2% of the total reviews for the years 2014 and 2015 respectively. Relatedly, within the year 2014 the highest number of recorded reviews were in the months of May, July, September. While within the year 2015, the highest number of reviews were recorded in the month of February (Appendix 7-10). In general, the years 2013 up to 2018 recorded the highest number of reviews (For Glucose Buddy Diabetes tracker app, about 1000 reviews were recorded and used for sentiment analysis (**Error! Not a valid bookmark self-reference.**). In

general, the positive polarity is divided into two polarities- positive and very positive, while the negative polarity is also classified into negative and very negative polarity.

Out of the 1000 reviews, about 539 (54.1%) reviews were categorized to have a positive polarity (**Error! Not a valid bookmark self-reference.**).

Table 5).

In total, about 539 and 117 reviews within the positive categorization were classified as positive and very positive respectively. In contrast, only a total of 16 and 151 reviews were classified as very negative and negative sentiments respectively (For Glucose Buddy Diabetes tracker app, about 1000 reviews were recorded and used for sentiment analysis (**Error! Not a valid bookmark self-reference.**). In general, the positive polarity is divided into two polarities- positive and very positive, while the negative polarity is also classified into negative and very negative polarity.

Out of the 1000 reviews, about 539 (54.1%) reviews were categorized to have a positive polarity (**Error! Not a valid bookmark self-reference.**).

Table 5).

For the Carb Manager – Keto Diet Tracker app, more than half of the recorded reviews (about 700 out of 1000) were categorized as very positive or positive (In general, only 16% of reviews were neutral and 14% were both negative and very negative. This is in contrasts with the recorded 69% positive or very positive classification.

Table 6). Furthermore, years 2019, 2021 and 2022 had the highest number of reviews at a total of 233, 305 and 239 respectively. Within these years, the highest number of recorded reviews were in the months of September, February, and March for the years 2019, 2021 and 2022 respectively (Appendix 11 - 13).

In general, only 16% of reviews were neutral and 14% were both negative and very negative. This is in contrasts with the recorded 69% positive or very positive classification.

Table 6: Sentiment analysis of a diabetes app ‘Carb Manager- Keto Diet Tracker’. using reviews from year 2018 to 2022 Sentiment analysis sentiment analysis was performed using the MeaningCloud (https://www.meaningcloud.com/). The expected classification is six possible levels of polarity, namely P

(pos-itive), N (negative), P+ (very positive), N+ (very negative), Neu (Neutral) and None (no polarity is detected).

Date	None	P+	P	Neu	N	N+	Total
2018	0	1	20	1	4	0	26
2019	0	17	167	28	21	0	233
2020	0	17	140	26	13	0	196
2021	0	12	137	77	78	1	305
2022	5	44	139	26	23	2	239
Total	5	91	603	158	139	3	999
Mean	1.0	18.2	120.6	31.6	27.8	0.6	199.8
%	0.5	9.1	60.4	15.8	13.9	0.3	100.0

5.4 Brand Performance and Value Analysis

Brand equity is the liabilities or assets associated with the brand that either adds to or reduces the value of the product the brand offers. To understand these liabilities and assets, a performance analysis comprising of PAR, BAR and NS were performed for the selected apps:

Purchase Action Ratio (PAR)

With a brand awareness of around 4300 for Glucose Buddy Diabetes Tracker and 3500 for Carb Manager- Keto Diet Tracker, the number of users who acted by downloading the app are relatively lower at 0.23 and 0.29 respectively (

Table 7).

Table 7: Purchase Action Ratio (PAR) of the two selected apps Glucose Buddy Diabetes Tracker and Carb Manager- Keto Diet Tracker. PAR measures the percentage of users in the market who spontaneously remembers a brand and acted either purchasing or downloading it.

	Glucose Buddy Diabetes Tracker	Carb Manager- Keto Diet Tracker
Act	997	999
Aware	4364	3499
PAR	0.23	0.29

Brand Advocacy Ratio (BAR)

The calculated BAR value for both selected apps Glucose Buddy Diabetes Tracker and Carb Manager- Keto Diet Tracker is at 0.01 and 0.02 respectively. Furthermore, the number of users that specified to advocate for both apps are at 44 and 62 respectively (Table 8).

Table 8: The BAR measures the percentage of users in the market who spontaneously remembers a brand and acted either purchasing or downloading it.

	Glucose Buddy Diabetes Tracker	Carb Manager- Keto Diet Tracker
Advocate	44	62
Aware	4364	3499
BAR	0.01	0.02

This number of users that advocated is relatively lower in comparison to the number of users that are aware of the apps at about 4300 for Glucose Buddy Diabetes Tracker and 3500 for Carb Manager- Keto Diet Tracker.

Net Sentiment Score (NS)

The value of Net Sentiment Score, ranging from 100 to -100, calculates a ratio of positive and negative mentions of a product. Thus, NS associated with the review is a proxy for the product performance or consumer satisfaction with the product (Rajeswari, Madhavan, Venkatesakumar, & Riasudeen, 2020).

Table 9: Net Sentiment Score for the two selected apps Glucose Buddy Diabetes Tracker and Carb Manager- Keto Diet Tracker. Net Score is represented as a percentage (%NS).

	Glucose Buddy Diabetes Tracker	Carb Manager- Keto Diet Tracker

Promoters (Positive and Positive plus)	656	694
Distractors (Negative and negative plus)	167	142
Total Response	997	999
%NS	82.55	83.68

Table 9 shows the reviews classified as both promoters and distractors across the selected apps; with the number of promoter reviews are higher in both apps when compared to the number of distractor reviews. Furthermore, the NS recorded as a percentage is at 83% for both selected apps.

Value Analysis

Value creation is an important ingredient in the competitive advantage of a firm and the performance of its strategy. Consequently, most business tries to ensure a value is incorporated into their product or services; and this directly or indirectly translates to a perceived benefit (consumer surplus).

Most customers of both selected apps- Carb Manager and Glucose Buddy Tracker have the same needs and expectation, as diabetic patients. The word cloud was used to illustrate the expected customer job for both apps, and it shows the word 'use' as the most frequently used at 66 and 124 times (Figure 17) for Glucose Buddy and Carb Manager respectively. Relatedly, other common activities performed by customers using these two apps were: 'track', 'log', 'read', 'update' etc.

The Pain section of the value proposition describes the difficulties the customers experience while trying to get their needs met, when using the app. While the Gain section describes the outcomes and benefits the customer wants, and the positive experience they get while using the app. To understand the Gain and Pain section of the value proposition chart of these selected apps, a co-occurrence chart was performed.

For the Glucose Buddy, the co-occurrence chart developed with the negative reviews (Figure 17a) show the user's most recorded pains are with the usage and updating the app, at 70 recorded frequencies. Furthermore, the areas of pains closely connected to the app usage includes logging

into the app, payment, and charges, tracking their blood sugar readings, manipulation, exporting and entering of data.

Using the positive reviews from the Glucose Buddy Tracker app to develop a co-occurrence chart, the most positive experience recorded term is usage, at 200 recorded frequencies. The other recorded gains and positive experience terms include the user's feelings while using the app, their simplicity and ease of operation. Closely connected to this and expressed as a Gain factor at 100 recorded frequencies are the two functionalities of tracking and logging in blood glucose value (Figure 17b).

For the Carb Manager app, the co-occurrence developed from the negative reviews showed app usage and update as the most recorded terms associated with pain, at 60 and 40 recorded frequencies respectively (Figure 19). Moreover, directly connected to these two pains associated terms are terms like 'difficult', 'freeze', 'slow', and 'look' etc. However, pain terms like 'try', 'pay', 'cancel' forms another separate network of words that are further indirectly connected to the pain term 'use'. Relatedly, forming a separate network of terms are the words 'terrible', 'scan' and 'frustrating', which existed separately without any connection (Figure 19a).

Describing the Gain factor of the value proposition formed by positive reviews of the Carb Manager app, positive term 'use' is the term with most frequency at 400, followed by 'great', 'track', 'easy', 'make', 'scan' all at the frequency of 300 (Figure 19b).

Furthermore, to answer research question 2 and 3 and to get evidence of a product fit between the product or service offered by the business the intended values of the two apps were compared. To achieve this, a domain comparison bar chart was constructed using the interview response from the three domains evaluated in the questionnaire (Figure 20).

a

b

Figure 17: A word cloud is the representation of the jobs the app users want to get done. The word cloud was done using an Excel Add-on software ChartExpo and using verbs from the users' reviews with neutral sentiment, which identifies technical functionality. Word cloud for a) Glucose Buddy, and b) Carb manager.

The Carb manager- Keto Diet Tracker shows a stronger domain percentage score at 55% in comparison to the 27% of Glucose Buddy Diabetes Tracker (Figure 20). However, the Glucose buddy app showed stronger percentage score within the clinical domain at 42% in comparison to the recorded 13% of the Carb Manager app (Figure 20). Both Glucose buddy and Carb Manager apps scored the same percentage score in usability at about 32% and 31% respectively (Figure 20).

In addition, the sentiment analysis comparison chart shows the comparison between both the positive and negative sentiments of both apps from year 01 January 2018 to 02 June 2022 (Figure 21). The highest positive reviews at 89% for Glucose Buddy was recorded in the year 2022, and 92% for Carb Manager in the year 2020. Moreover, the recorded positive reviews increase from year 2018 to 2022 for Glucose Buddy, but the recorded values of the negative reviews remained constant across the years (Figure 21). This observed constant negative reviews was also similar for the Carb Manager app, except for the slight increased in value in the year 2021 (Figure 21).

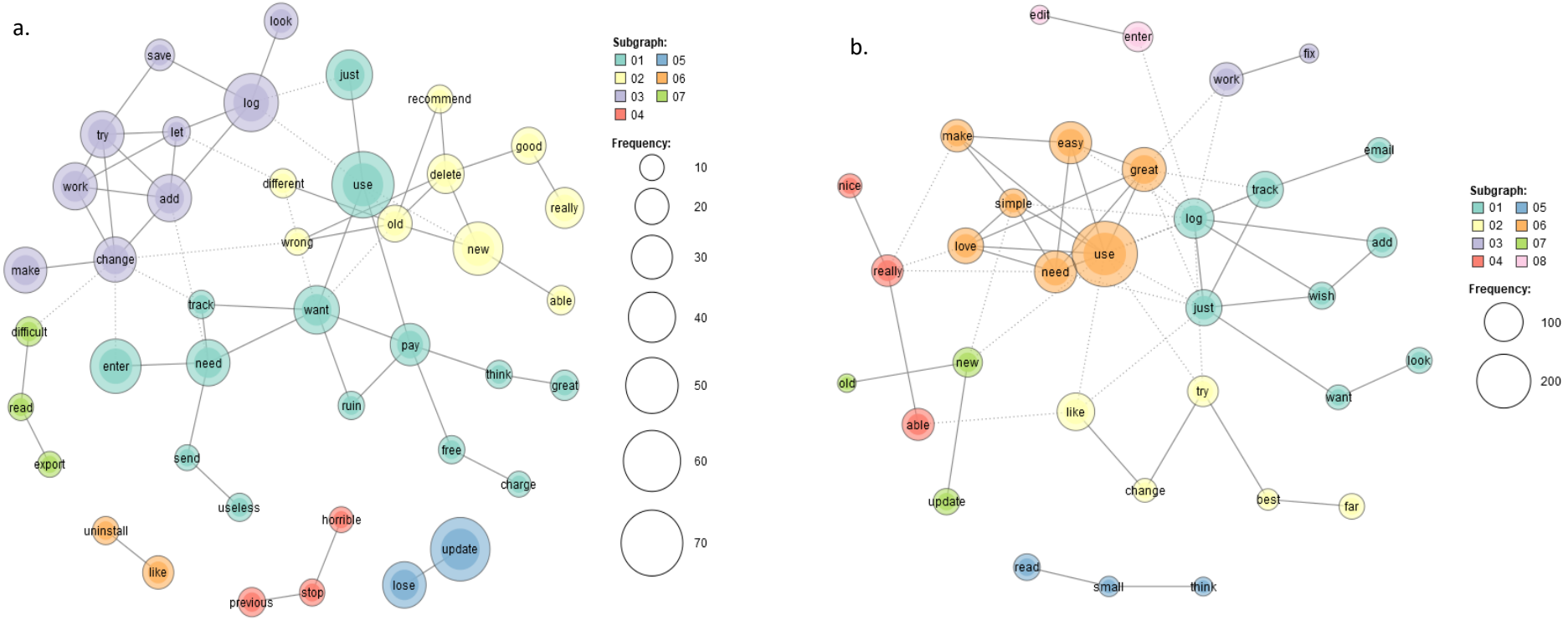

Figure 18: Co-occurrence is a visual representation of a sematic network analysis that is used to illustrate relationship between words in a text and shows a collective interconnection of words based on their connecting relationship to form a network. Co-occurrence analysis on Glucose Buddy app was performed using KH Coder (http://khcoder.net/en/) on a) negative reviews, and b) positive reviews.

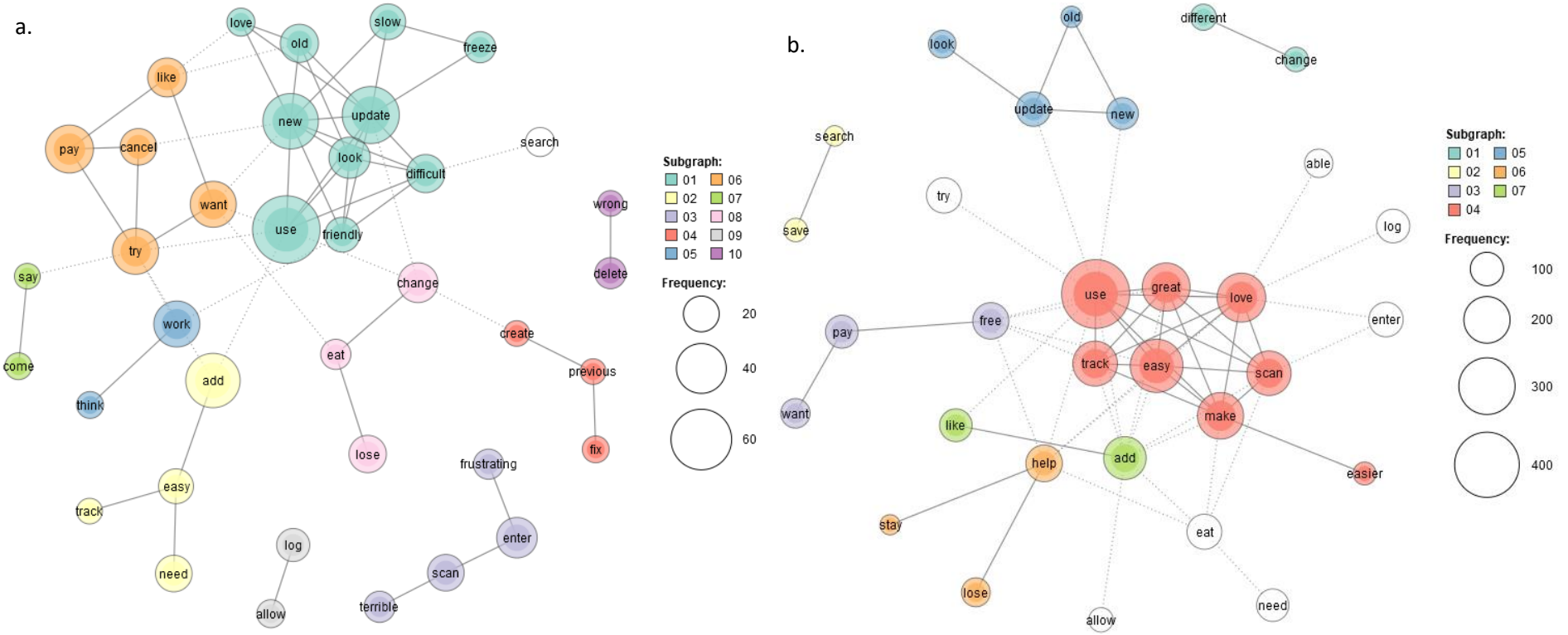

Figure 19: Co-occurrence is a visual representation of a sematic network analysis that is used to illustrate relationship between words in a text and shows a collective interconnection of words based on their connecting relationship to form a network. Co-occurrence analysis on Carb Manager app was performed using KH Coder (http://khcoder.net/en/) on a) negative reviews, and b) positive review.

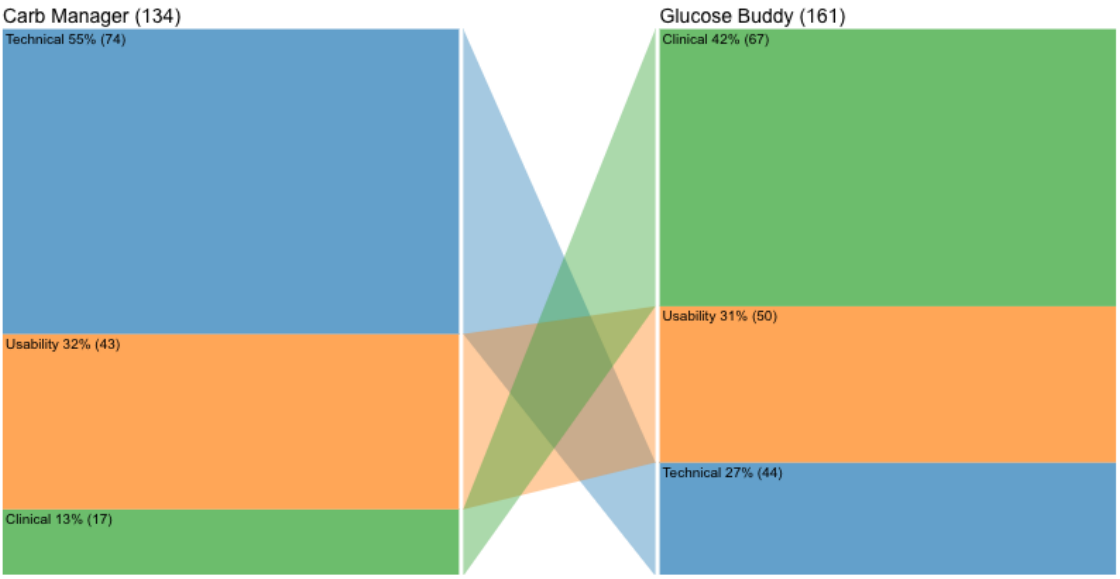

Figure 20: Domain comparison compares the three domains of technical, usability and clinical using the response data from the questionnaire. The percentage score is shown in bracket, which was calculated based on the scoring of the interview questions. However, the percentage score depicted in the diagram is based on the summation of the scores of the three domains together. The domain comparison bar chart was built with an Excel Add-on software ChartExpo.

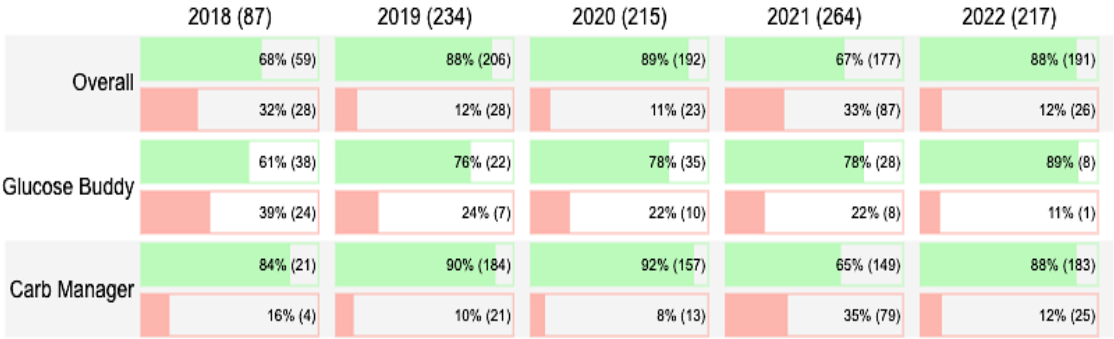

Figure 21: Comparison of the reviews of both positive and negative polarities from year 2018 to 2022 shown as a sentiment comparison chart.

5.5 Development Task

Prior to the start of this research, the expertise of the researcher is limited to both scientific and user-insight analytical skills. However, the research work provided the opportunity to further improve on the researcher's knowledge in business, brand management and marketing.

From another viewpoint, the prospect of this project is to help the commissioner to set up a theoretical framework with a proven practical application in the development of a digital platform to analyse mobile health apps. This prospect is related to the future goal of the commissioner, which is to develop a functional digital platform. The envisaged digital platform will be a web-client program with capability to self-analyse submitted digital mobile apps, with results focusing on performance and health metrics, covering technical, clinical, and brand management.

The result of this research work will help in the development of the digital platform from two perspectives. First, both health behavioural change models and brand equity models used in the analysis serve as a foundation towards developing a framework from which the digital platform will be built. In addition, future frameworks outside the mobile health apps but specific to other different industries can be developed using the same approach used in this research work.

Moreover, there are some planned analytical services that the digital platform can provide namely, benchmark analysis as done by comparing the two selected diabetes apps in this research work. The comparative approach developed in this study serve as an operational guide for such benchmark analytical service. In addition, a product development strategy evaluation service could be performed using the correlation between app version upgrades and users' review sentiment analysis, as done in the research work.

The question is therefore, why now? What is the rationale behind this timing for a need of such a digital platform? The answer lies in the need for regulation and the speed at which mobile health apps have been developed. It is not new that a lot of research and guidelines have been proposed to regulate the myriad of digital health mobile apps; and most of these guidelines focus on the clinical significance and validity of these apps. However, what is missing are the marketing and brand performance metrics for these mobile health apps despite the continuous evidence of their importance. This study provided a framework to address the above identified gap; and further showed the possibility of addressing the potential need for businesses looking for ways to identify unoptimized domains within their brand specific mobile applications.

The target users of the proposed digital platform are digital health start-ups, pharmaceuticals, consulting firms operating within the pharmaceutical industry.

Finally, the proposed digital platform will form an integral part of the commissioner's business model with an ecosystem, comprising of a) the capacity to analyse mobile health apps, and b) serve as a platform to connect external clients and developers to carry out other analysis related to market analysis, value, and brand performance.

6 Discussions and Conclusion

There is a very huge expectation regarding the potential of mHealth, however, it has mostly failed to achieve this expectation mostly due to lack of adoption. There has been considerable effort in the clinical validation to help with the adoption of the mHealth apps (Larson, 2018), but their market and brand performance has been largely left unaddressed. In connection to validating the market and brand performance of the selected apps, our discussion will follow the three research questions stated at the beginning of the research work.

The first research question is to understand how the sentiment and perception towards the two selected mobile apps change with the different digital marketing strategies. Mobile apps are software products, and a release of an upgrade is considered a marketing strategy that requires a comprehensive information and knowledge (Nayebi, Adams, & Ruhe, 2019).

This part of the research work on the sentiment analysis showed that several factors in the background influence the engagement of the user and how users feel about using the app (Meyer & Okuboyejo, 2021). There is a close similarity in value between the reviews with neutral sentiment to those with both Negative and Negative + (plus) polarities for the Glucose Buddy app, at 13.3% compared to 16.7%. Furthermore, from the analysis of the Carb Manager reviews the same similarity trend between reviews with neutral and negative polarity was observed, at 15.8% compared to 14.2% respectively (Table 6). This similarity between the total neutral and negative reviews, as observed in both apps, can be because of two reasons. Firstly, it might be showing that while the users have formed a clear opinion regarding positive emotions associated with the app usages (54% of total reviews are positive), some users might still not be clear on how they classify their experience. This line of thought was be supported when we randomly select reviews that were classified as negative and neutral polarity to further analyse the intention and emotions of the user within the context of the sentence. For example, below are two reviews with neutral polarity from Glucose Buddy app:

'[…] Does decent tracking but DON'T PAY FOR PREMIUM!!'

'This app USED to be a good blood glucose tracker that offered med tracking and other important health tracking. Key word USED TO. Current update SUCKS! Does allow medications to be deleted. Checks and inserts other meds not added and then won't let you log any input. They tried to hard

to make it easier to read and analyze the data. You RUINED a perfectly good app with lots of potential. Please fix and respond. Otherwise, I'll have to delete and recommend something better.'

The alternative explanation is because of the limitation of the polarity model used in the classification by the algorithm. Kritikos, Venetis, & Stamelos, (2020) also discovered such limitation in the polarity and irony classification of the Meaning Cloud algorithm.

Further examination of the Glucose Buddy's reviews with positive polarity showed the months of May, July, and September (2014) and February (2015) are with highest reviews (Table 5). This trend coincided with the date of upgrade of the app. For instance, in the year 2014, version 1 was released in August and an increase in positive reviews was observed in the following month of September. This is also as evident from some of the reviews from September 2014, as shown below:

'This is a great app, and I am sure it will continue to improve as the developers get feedback. […]

'Works great. Love the email data to yourself feature. I use that before doctor visits to show quarterly trends. I also track blood pressure readings. Like others, I wish the "coming soon" sync feature would happen. I hope the creator has not forgotten.'

Furthermore, for the Carb Manager app the highest number of recorded reviews were in the months of September, February, and March of the years 2019, 2021 and 2022 respectively. A similar trend of increase in number of recorded positive reviews with the app upgrade was also observed. For instance, three new versions of the Carb Manager app were released in the month of February 2021 and coinciding with a 2% increase in the recorded positive reviews for the app.

Evidently, our sentiment analysis result shows that the sentiment of the users changes with the app version upgrade, answering the first research question. This result means that the observed sentiment of the two apps is expressed as positive emotions, probably because the app upgrades addressed the needs of the users. Typically, app version upgrades tend to focus on improving functionality, time, and quality; and greatly depends on the market and perceived risk (Nayebi et al., 2019).

However, mobile apps like all products do not only depends on their features rather developers of these apps and most brands focus on how to create values that resonate with users; and consequently, build these features or capability of value creation into the app (Ntui, 2021). These created values and features constitute the brand equity of the app. Simply defined, brand equity

is equivalent to the value of the brand, without a branded name attached to it (Elliott, Rosenbaum-Elliott, Percy, & Pervan, 2011).

To understand the values and intangible assets of these two selected apps, we asked the question on how the value and market performance of these two selected apps compare to each other. According to Aaker, (2009) the key component of the brand equity (value of the brand) includes brand awareness, brand association, perceived quality, brand loyalty, and other proprietary assets.

Our brand awareness analysis comparison of the two apps was done by calculating the PAR, with Glucose Buddy and Carb Manager apps having PAR values of 23% and 29% respectively. This measure of functional experience, while using the app, means that Glucose Buddy and Carb Manager activates only suboptimal 23% and 29% of their spending to generate market share respectively, as against the ideal PAR score of 100%. Sugiyanto & Wicaksono, (2020) also observed a low 24% PAR value in their app performance analysis in the transport industry. Furthermore, the recorded BAR values for both apps are also relatively low at 0.01 and 0.02 for Glucose Buddy and Carb Manager respectively. BAR is a measure of a loyalty. Therefore, put simply, the BAR result indicates that one out of the 100 people who are aware of Glucose Buddy recommends it; and only two people out of 100 recommends Carb Manager.

In contrast, an 85% PAR value and 92% BAR value were reported for a company within the food and beverage industry (Ulumuddin & Wibowo, 2021). This observed difference in the values of PAR and BAR could be because of the industry type and difference in products offered. Already, there are five identified industry archetypes based on customer behaviour and journey (Kartajaya et al., 2016). It appears that the mobile health app industry falls within the archetype Doorknob. This industry is characterized with low affinity to the brand and unwillingness to recommend the brand. In addition, brand switching is common, most especially because of the low-price points (Kartajaya et al., 2016). This is against the food and beverage industry that is a Goldfish archetype (Ulumuddin & Wibowo, 2021).

Furthermore, the other component of brand equity is brand association. Brand association essentially examines the features of a product and functional and emotional benefits that evokes positive or negative sentiments. The Net Sentiment Score was calculated to give information about the overall user's sentiment of the two selected apps. At +83% for Glucose Buddy and Carb Manager, the overall sentiment for both selected apps are highly positive. Moreover, to understand the features that influences this sentiment, the co-occurrence result using positive

reviews indicate that for both apps, the positive emotion is associated with the usage of the app and other functional benefits involving tracking and logging of blood glucose values.

In summary, the answer to the research question about how the value and market performance of these two selected apps compare to each other indicates that both apps are very similar in comparison. This is an indication of the doorknob archetype and the highly competitive nature of the industry landscape. In addition, the developers of both brands are attuned to the industry landscape, and this is reflective of their apps. This similarity reflects competitive strategy, and it thereby ensures individual brands can compete actively. Along this line of reasoning, one of the characteristics of the mobile health apps market landscape is that players within this industry comprise of a very large number of small, mid-size, and large companies and competition is intensely high (Paglialonga, Schiavo, & Caiani, 2018). Furthermore, there are currently about 100,000 mHealth apps published in the health and wellness section of both Apple's App Store and Google Play. However, only the minority elite mHealth publishers, which represent only 5% of the whole mHealth app publishers, generated a revenue of more than USD 1 million in the year 2013 (Dehzad, Hilhorst, de Bie, & Claassen, 2014).

Finally, as the potential and accessibility of mHealth apps increases regarding diagnosing, monitoring, and treating of chronic conditions, usability of these apps becomes an important factor to ensure the values these apps aim to provide and the needs of the users are met (Pai, 2022; Potgieter & Rensleigh, 2022). To answer if the two selected apps in our research addresses the needs of the targeted users (Research Question 3), we performed usability and user-requirement analysis and compared the results of the two apps (Figure 16 and Figure 20).

Our usability and user-requirement analysis started with nine apps, and all the nine analysed apps showed evidence of usability and user-requirement being considered in the development of the apps. However, the two selected apps Glucose Buddy and Carb Manager scored lower than the domain average score of 52% (Figure 14). Further comparison of the two apps with focus on the usability and user-requirement domain showed that Carb Manager's score was about 7% lower in comparison to that of Glucose Buddy (Figure 20). To understand the cause of this low score, examination of the interview questionnaires (Appendix 1 - 2) showed that both apps were not strong in the psychological support either via online medium or in-person contacts category of useability and user-requirement domain. However, the need of psychological support is important to help alleviate the feelings of loneliness; and provides necessary information needed to solve complex problems and alleviate mental stress often associated with chronic diseases, like

diabetes (Papaspurou et al., 2015). In addition, Carb Manager scored lower in self-management and education category of the usability and user-requirement domain.

However, the categories of usability and user-requirement that has been mostly assessed in other mHealth apps is understandability (Zapata, Fernández-Alemán, Idri, & Toval, 2015). This category assesses, among other things, how easy it is to understand the texts used in the app and texts should be presented in layman terms (Khan, Tahir, & Raza, 2013; Zapata et al., 2015). Interestingly, both selected apps scored high in this category depicting that the text used in these two apps correspond to the needs and incorporated typical vocabularies used by the target users (Zapata et al., 2015).

In conclusion, this study confirmed that there is a possibility to develop a framework combining both theoretical models and brand performance models to be able to validate the performance of mobile apps. In addition, the finding indicates the potential value the diabetes app provides in the self-management of diabetes. However, app developers need to understand the ever increasing and changing landscape within the industry; and thus, the need to be flexible and up to date to the changes of the stringent regulations in this highly regulated environment.

Research Questions, Findings and Future Works

The summary of the research findings to all the formulated research questions are listed below:

a. How has the customer's sentiment and perception change with the different digital marketing strategies of the selected apps?

   Product upgrade, i.e., app version upgrade, is an example of marketing strategies within software industry, like mHealth. For both apps, version upgrades coincided with an increase in positive reviews.

b. How does the marketing performance, in terms of value creation, of the selected apps compare among themselves?

   By comparison, the value and market performance of these two selected apps are very similar. This is an indication of awareness of the market landscape by both brands, and a competitive strategy to navigate the landscape.

c. Did the selected Apps meet the needs of the targeted patient group? How?

No, for both selected apps. Our analysis indicates a below average score in the usability and user requirement domain. Decomposing the result of both apps:

- *Both apps scored lower in the psychological support either via online medium or in-person contacts category*
- *Only Carb Manager scored lower in self-management and education category*

The theoretical framework presented at the start of the write-up showed the possible theoretical framework for evaluating the digital market and brand performance of digital assets (mobile applications). The focus and approach are to combine a brand equity model with a health behavioural change model in the evaluation of mobile applications. Relatedly, the presented empirical result confirmed this assumption and showed the use of brand equity model (Aaker model) to quantify the numerical value of the brand equity of the selected digital application assets. A similar approach has been used by one of the top brand consulting companies (Interbrand www.interbrand.com). In contrast, Interbrand's approach was to quantify the financial value of the brand equity of some selected businesses (https://interbrand.com/best-brands/).

Borrowing from the case of Interbrand, a future research perspective could be incorporating the financial metrics into the evaluation of the mobile applications to give a complete overview, encompassing both the market and financial value of the brand equity. In addition, a future application direction could be adapting this empirical result and framework to other industries. With the rise of luxury wellness industry within the healthcare, this industry is a logical direction for the commissioner to examine.

Reliability and Validity

Despite the planned effort for an accurate and objective research work and result, this study might have some limitations regarding reliability and validity. These limitations cover the areas of methodology, result, external and internal:

Methodology

Relevant software for extraction of reviews were used, and the major platforms for app publishing. However, due to some rules from using these third-party vendors and platforms, relevant reviews might have been omitted. To increase validity, multiple platforms were used outside the two major ones; and different web-crawling software were tried before a final

decision was made. In addition, the app selection methodology used is a combination of two methods that have not been used together before, this might have resulted in omission of important apps as part of the final selected mHealth apps.

Result

Relevant research question(s) may have been overlooked during the formation of the research questions for the research project, thus limiting the robustness of the information that could be derived from the result.

External

The service of an independent reviewer was sorted as part of the effort to ensure data triangulation and increased validity of result. However, only one external reviewer performed the interview-questionnaire analysis. This might threaten the validity of the result. However, as it is part of triangulation used in combination with other results the effect is expected to be invalidated at the end.

Internal

The author is knowledgeable and with the support of a supervisor. There is no expected thread in this instance and context.

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Thesis material management plan

Attached to the thesis

1. General description of the material

Research materials include Tweets, user reviews, star ratings, number of users, App description.

2. Documentation and quality of the material

Research data are left as original as possible to ensure quality. The only scenario of manipulation of data will be during transformation and data analysis, whereby such transformation will follow correct process.

3. Storage and backup

Data obtained during the research process will be stored on local drive, and with no third-party access. An external pen-drive will be used as a back-up device, and with no third-party access.

4. Ethical and legal issues related to storage

There are no foreseen ethical issues related to material storage because data that will be used will be from public domains, and usually username are pseudonymised. In case of real name is used, online free resource to generate a universally unique identifier will be used.

5. Opening the material and long-term storage

Raw data obtained from the data source will be stored in excel and submitted as part of supplementary materials for future use

	Assessment Criteria	Points (0 = none; 1 = partial 2 = full)	Section Total
Technical Questions			
Security	Does the application require a login?	0 to 2	Add up individual scores
	Is sensitive data stored on the cloud?	0 to 2	
	Has the application been certified by any 3rd party security vendors?	0 to 2	
Privacy	Does the application state compliance with HIPAA (1) and/or GDPR (2)	0 to 2	Record individual score
Interoperability	Does the application provide a means to export user's data (e.g. PDF (1), CSV (2), JSON (2)?	PDF = 1 CSV = 2 JASON = 2	Record individual score
Performance	Does the application crash close regularly?	0 to 2	Add up individual scores
	Is there documentation the application content been updated within the past 3 months (2) or 6 months (1)?	Past 3 months = 2 Past 6 months = 1	
Health and Clinical Questions			
Clinical credibility	Does the technology make a clinical claim to impact a health outcome? If yes, see below (in blue text)	0 = no and proceed to Credibility	Add up individual scores
	Produced by Recognized medical institution or organization	0 = no; 3= yes	Add up individual scores
	Produced by Recognized medical individual or team	0 = no; 2 = yes	
	None of the above	0 = yes	
	Is the clinical claim made by the app supported by reference in any research articles?	0 = no; 1 = yes	Add up individual scores
Technical Questions			
Visual Design & Readability	When possible, reduce the probability of data entry error by providing users with selectable options rather than requiring text entry.	0 or 1	Add up individual scores
	Text should avoid use of jargon or acronyms that may not be familiar to users, particularly for lay users without clinical knowledge.	0 or 1	
App Navigation	Users should be able to easily identify where they are in the app and how to navigate to different destinations, including reversing actions. The navigational path should be logical, predictable, and easy to follow.	0 to 2	Record individual score

Notifications, Alerts	Users should be given the choice to opt out of automatic non-critical notifications and alerts.	0 to 2	Record individual score
Help Resources & Support	Human support is provided in addition to digital support	0 or 1	Record individual score
Context & Personalization	Content and screens are personalized based on individual user situation and needs	0 or 2	Record individual score
Usability & User-requirement Questions			
User's needs Education	The app must have educational content around diabetes (and self-management of he disease) that can be individually personalized, either via search or updates	Points (0 = none; 1 = partial 2 = full) 0 to 2	Add up individual scores
	The app content should be presented in layman's terms/ easy to understand	Points (0 = none; 1 = partial 2 = full) 0 to 2	
User's needs Social and psychological Support	The app must have choice to connect to family and friends, and diabetes online community	Points (0 = none; 1 = partial 2 = full) 0 to 2	Add up individual scores
	The app must connect w/ an online community of similar patients - forums, social media , direct chat	Points (0 = none; 1 = partial 2 = full) 0 to 2	
User's needs for communication & disease prevention	The app must have ability to connect/ message my healthcare team/ provider	Points (0 = none; 1 = partial 2 = full) 0 to 2	Add up individual scores
	The app must log my symptoms and view them historically; and can provide a summarized pattern of my medication intake or/and blood glucose tracking	Points (0 = none; 1 = partial 2 = full) 0 to 2	
User's needs for awareness & disease prevention	The app must provide personalized risk assessments related to hypo- /hyperglycaemia and other diabetis associated diseases	Points (0 = none; 1 = partial 2 = full) 0 to 2	Add up individual scores

Appendix 1: Questions listed in the questionnaire that was administered during the interview

nBuddy Diabetes						
#1						
Date	None	P+	P	Neu	N	N+
Jan-18	0	0	0	0	1	0
Mar-18	0	2	1	0	0	0
Sep-18	0	1	1	0	0	0
Oct-18	0	1	2	0	0	0
#2						
Date	None	P+	P	Neu	N	N+
Feb-19	0	0	1	0	0	0
Mar-19	0	1	0	0	0	0
Jun-19	0	1	0	0	0	0
Jul-19	0	0	1	0	0	0
Oct-19	0	0	1	0	0	0
#3						
Date	None	P+	P	Neu	N	N+
May-20	1	0	0	0	0	0
Jul-20	1	0	0	0	0	0
Aug-20	1	0	0	0	0	0
Nov-20	0	0	0	0	1	0
#4						
Date	None	P+	P	Neu	N	N+
Apr-21	0	0	1	0	0	0
#5						
Date	None	P+	P	Neu	N	N+
Feb-22	0	0	1	0	0	0
Mar-22	0	0	2	0	0	0
DiabTrend						
#1						
Date	None	P+	P	Neu	N	N+
May-19	0	0	1	0	0	0
Jul-19	1	0	1	0	0	0
Aug-19	0	0	1	0	0	0
Oct-19	0	1	0	0	0	0
#2						
Date	None	P+	P	Neu	N	N+
Oct-20	0	0	0	0	1	0
#3						
Date	None	P+	P	Neu	N	N+
Feb-21	0	0	1	0	0	0
Apr-21	0	0	0	0	1	0

May-21	0	1	0	0	0	0
Nov-21	1	0	1	0	1	0
Dec-21	0	0	0	0	0	1
#4						
Date	None	P+	P	Neu	N	N+
Feb-22	0	0	1	0	0	0
Diabetes Forum						
#1						
Date	None	P+	P	Neu	N	N+
Jan-13	3	3	3	0	0	0
Mar-13	0	0	2	0	0	0
Apr-13	1	3	4	0	0	0
May-13	1	1	3	1	0	0
Jun-13	0	1	1	0	0	0
Jul-13	1	2	2	0	1	0
Aug-13	0	2	2	0	0	0
Sep-13	0	0	1	0	0	0
Oct-13	1	0	3	0	1	0
Nov-13	1	1	1	1	0	0
Dec-13	1	0	1	0	1	0
#2						
Date	None	P+	P	Neu	N	N+
Jan-14	0	0	2	0	1	1
Feb-14	0	0	0	0	0	0
Mar-14	0	1	1		0	0
Apr-14	0	1	2	1	0	0
May-14	0	2	2		0	0
Jun-14	0	1	4	0	2	0
Jul-14	2	3	4	0	1	0
Aug-14	0	3	2	1	1	0
Sep-14	1	3	3	0	2	0
Oct-14	0	2	4	1	1	0
Nov-14	2	5	1	0	1	0
Dec-14	0	1	2	0	0	0
#3						
Date	None	P+	P	Neu	N	N+
Jan-15	1	2	1	1	0	0
Feb-15	0	1	3	1	0	0
Mar-15	3	0	4	1	1	0
Apr-15	1	2	0	0	1	0
May-15	0	1	2	0	0	0
Jun-15	2	2	2	1	2	0
Jul-15	2	1	2	1	1	0
Aug-15	0	2	0	0	1	0
Sep-15	1	0	6	0	1	0
Oct-15	0	1	5	0	0	0
Nov-15	1	0	4	0	1	0
Dec-15	0	0	2	0	0	0

#6						
Date	None	P+	P	Neu	N	N+
Jan-16	0	1	4	0	0	0
Feb-16	1	0	0	0	0	0
Mar-16	0	1	1	0	1	0
May-16	0	0	3	1	0	0
Jun-16	0	0	3	0	2	0
Jul-16	1	0	0	0	0	0
Aug-16	0	0	3	1	0	0
Sep-16	0	0	0	0	1	0
Oct-16	0	1	0	0	0	0
Nov-16	0	1	0	0	0	0
#7						
Date	None	P+	P	Neu	N	N+
Jan-17	1	0	1	1	0	0
Feb-17	0	0	1	0	0	0
Apr-17	0	0	1	0	1	0
May-17	0	0	0	0	0	1
Jun-17	0	1	0	0	0	0
Aug-17	1	0	1	0	1	0
Sep-17	0	2	2	0	0	0
Nov-17	0	0	3	1	0	0
#8						
Date	None	P+	P	Neu	N	N+
Jan-18	0	2	1	1	0	0
Feb-18	0	1	1	0	0	0
Apr-18	0	1	0	2	2	0
May-18	1	2	2	1	0	0
Jun-18	0	0	4	0	1	0
Jul-18	1	1	0	0	2	0
Aug-18	0	1	0	0	0	0
Sep-18	1	1	0	0	3	0
Oct-18	0	0	1	0	0	0
Nov-18	0	0	0	1	0	0
Dec-18	0	1	1	0	0	0
#9						
Date	None	P+	P	Neu	N	N+
Jan-19	0	2	0	0	0	0
Feb-19	0	1	0	0	0	0
Apr-19	0	3	0	0	0	0
May-19	0	1	2	0	1	0
Aug-19	0	0	0	0	1	0
Sep-19	1	1	1	1	0	0
Nov-19	0	0	1	0	0	0
Dec-19	0	0	0	0	1	0
#10						
Date	None	P+	P	Neu	N	N+

Jan-20	1	0	0	0	1	0
Mar-20	0	0	3	1	0	0
Apr-20	0	1	1	1	1	0
May-20	0	1	0	0	0	0
Jun-20	1	0	0	0	1	0
Aug-20	0	0	0	0	1	0
Sep-20	0	1	1	0	0	0
Oct-20	1	1	0	1	0	0
#10						
Date	None	P+	P	Neu	N	N+
Jan-21	0	1	0	0	0	0
Mar-21	1	0	0	0	0	0
Apr-21	0	0	0	1	0	0
May-21	0	0	0	1	0	0
Jun-21	0	0	0	0	0	1
#11						
Date	None	P+	P	Neu	N	N+
Jan-22	0	0	0	0	2	0
Feb-22	0	0	1	0	1	0
Apr-22	0	0	0	0	1	0
Defeat Diabetes						
#1						
Date	None	P+	P	Neu	N	N+
Jan-22	1	0	2	2	3	0
Feb-22	0	0	2	0	2	0
Mar-22	0	0	3	0	0	0
Apr-22	0	0	1	0	0	0
May-22	0	0	1	0	0	0
Jun-22	0	0	0	0	1	0
Jul-22	0	0	2	0	0	0
Aug-22	0	0	2	1	0	0
Sep-22	0	0	0	0	2	0
Oct-22	1	0	0	0	0	0
Nov-22	0	0	0	0	1	0
Dec-22	1	0	1	0	0	0
#2						
Date	None	P+	P	Neu	N	N+
Jan-22	1	0	0	1	0	0
Total	1	0	0	1	0	0
BeatO Smart						
Date	None	P+	P	Neu	N	N+
Aug-19	0	0	1	0	0	0
Oct-19	0	0	0	0	1	0
Dec-19	0	0	0	0	1	0
Jun-21	0	1	0	0	0	0
Nov-21	0	0	1	0	0	0

Dec-21	0	0	1	1	1	0
Jan-22	1	1	1	0	4	1
Feb-22	0	4	5	1	4	0
Mar-22	0	3	23	5	13	0
Apr-22	1	8	20	2	5	0
May-22	0	1	3	2	4	0

Appendix 3 – 7: Sentiment analysis of the remaining five selected diabetes apps, namely BeatO Smart, Defeat Diabetes, Diabetes Forum, DiabTrend and nBuddy Diabetes.

#1	Glucose Buddy						
Date	None	P+	P	Neu	N	N+	Total
Jul-12	0	0	1	0	1	0	2
Sep-12	0	0	1	0	0	0	1
Nov-12	0	0	2	1	0	0	3
Dec-12	0	0	2	0	1	0	3
Total	0	0	6	1	2	0	9
Mean	0.0	0.0	1.5	0.3	0.5	0.0	2.3
%	0.0	0.0	66.7	11.1	22.2	0.0	100.0
#2							
Date	None	P+	P	Neu	N	N+	Total
Jan-13	0	1	1	0	0	0	2
Feb-13	0	0	4	0	0	0	4
Mar-13	0	0	4	1	0	0	5
Apr-13	0	0	1	0	0	0	1
May-13	0	1	4	0	0	0	5
Jun-13	0	0	2	0	1	0	3
Jul-13	0	0	4	0	1	0	5
Aug-13	0	0	4	0	0	0	4
Sep-13	0	0	2	1	0	0	3
Oct-13	0	0	1	1	2	0	4
Nov-13	0	0	5	1	0	0	6
Dec-13	0	0	3	1	1	0	5
Total	0	2	35	5	5	0	47
Mean	0.0	0.2	2.9	0.4	0.4	0.0	3.9
%	0.0	4.3	74.5	10.6	10.6	0.0	100.0
#3							
Date	None	P+	P	Neu	N	N+	Total
Jan-14	0	0	2	0	0	0	2
Feb-14	0	0	1	1	1	0	3
Mar-14	0	0	7	2	0	0	9
Apr-14	0	0	2	0	2	0	4
May-14	0	0	5	2	1	0	8
Jun-14	0	0	2	0	2	0	4
Jul-14	0	0	4	0	0	0	4
Aug-14	0	0	5	0	0	0	5

Sep-14	0	2	1	1	0	0	4
Oct-14	0	1	4	0	1	0	6
Nov-14	0	0	3	0	1	0	4
Dec-14	0	0	2	1	1	0	4
Total	0	3	38	7	9	0	57
Mean	0.0	0.3	3.2	0.6	0.8	0.0	4.8
%	0.0	5.3	66.7	12.3	15.8	0.0	100.0
#4							
Date	None	P+	P	Neu	N	N+	Total
Jan-15	0	1	2	1	1	0	5
Feb-15	0	0	2	0	1	0	3
Mar-15	0	1	3	1	1	0	6
Apr-15	0	0	1	2	0	0	3
May-15	0	0	2	1	0	0	3
Jun-15	0	0	2	1	0	0	3
Jul-15	0	0	3	0	0	0	3
Aug-15	0	0	3	0	1	0	4
Sep-15	0	0	5	0	0	0	5
Oct-15	0	0	4	2	0	0	6
Nov-15	0	0	1	1	0	0	2
Dec-15	0	0	2	1	0	0	3
Total	0	2	30	10	4	0	46
Mean	0.0	0.2	2.5	0.8	0.3	0.0	3.8
%	0.0	4.3	65.2	21.7	8.7	0.0	100.0
#5							
Date	None	P+	P	Neu	N	N+	Total
Jan-16	0	0	2	1	2	0	5
Feb-16	0	0	1	0	0	0	1
Mar-16	0	0	1	0	0	0	1
Apr-16	0	0	2	0	0	0	2
May-16	0	0	1	0	0	0	1
Jun-16	0	0	2	0	2	0	4
Jul-16	0	0	0	0	1	0	1
Sep-16	0	0	1	0	0	1	2
Nov-16	0	0	1	0	0	0	1
Dec-16	0	0	1	0	0	0	1
Total	0	0	12	1	5	1	19
Mean	0.0	0.0	1.2	0.1	0.5	0.1	1.9
%	0.0	0.0	63.2	5.3	26.3	5.3	100.0
#6							
Date	None	P+	P	Neu	N	N+	Total
Jan-17	0	0	2	0	0	0	2
Feb-17	0	0	4	0	0	0	4
Apr-17	0	0	1	0	0	0	1

Jun-17	0	0	2	0	0	0	2
Jul-17	0	0	1	0	1	0	2
Aug-17	0	0	1	1	0	0	2
Sep-17	0	0	0	1	0	0	1
Nov-17	0	0	1	0	1	0	2
Dec-17	3	6	20	16	22	6	73
Total	3	6	32	18	24	6	89
Mean	0.3	0.7	3.6	2.0	2.7	0.7	9.9
%	3.4	6.7	36.0	20.2	27.0	6.7	100.0
#7							
Date	None	P+	P	Neu	N	N+	Total
Jan-18	4	1	10	6	11	0	32
Feb-18	0	2	8	0	2	1	13
Mar-18	0	0	2	0	0	0	2
Apr-18	0	1	2	2	3	0	8
May-18	1	1	4	0	1	0	7
Jun-18	0	0	0	1	0	0	1
Jul-18	0	0	2	1	1	0	4
Aug-18	1	2	0	0	0	1	4
Sep-18	1	0	0	0	1	0	2
Oct-18	1	0	0	1	1	0	3
Nov-18	0	1	1	1	0	0	3
Dec-18	0	0	0	1	1	0	2
Total	8	8	29	13	21	2	81
Mean	0.7	0.7	2.4	1.1	1.8	0.2	6.8
%	9.9	9.9	35.8	16.0	25.9	2.5	100.0
#8							
Date	None	P+	P	Neu	N	N+	Total
Jan-19	0	0	3	1	0	0	4
Feb-19	0	0	0	1	1	0	2
Mar-19	1	0	1	1	2	0	5
Apr-19	0	0	2	0	2	0	4
May-19	0	1	0	0	0	0	1
Jun-19	0	1	1	0	0	0	2
Jul-19	0	0	1	0	1	0	2
Aug-19	0	0	1	0	0	0	1
Sep-19	0	0	1	0	0	0	1
Oct-19	0	0	1	0	0	0	1
Nov-19	0	2	5	1	1	0	9
Dec-19	1	2	0	0	0	0	0
Total	2	6	16	4	7	0	35
Mean	0.2	0.5	1.3	0.3	0.6	0.0	2.7
%	5.7	17.1	45.7	11.4	20.0	0.0	100.0
#9							

Date	None	P+	P	Neu	N	N+	Total
Jan-20	0	2	3	0	1	0	6
Feb-20	0	2	2	0	0	0	4
Mar-20	0	0	2	1	0	0	3
Apr-20	1	1	3	1	1	0	7
May-20	0	1	1	0	1	0	3
Jun-20	0	0	3	0	0	0	3
Jul-20	3	0	5	1	3	0	12
Aug-20	0	0	3	1	2	0	6
Sep-20	0	0	3	0	1	0	4
Oct-20	1	0	1	0	0	0	2
Nov-20	1	0	1	0	0	0	2
Dec-20	0	1	1	2	1	0	5
Total	6	7	28	6	10	0	57
Mean	0.5	0.6	2.3	0.5	0.8	0.0	4.8
%	10.5	12.3	49.1	10.5	17.5	0.0	100.0
#10							
Date	None	P+	P	Neu	N	N+	Total
Jan-21	2	0	3	1	1	0	7
Feb-21	0	0	3	2	1	0	6
Mar-21	0	2	4	0	0	0	6
Apr-21	1	2	1	1	2	0	7
May-21	2	0	4	0	0	0	6
Jun-21	0	1	0	0	1	0	2
Jul-21	0	1	0	0	0	0	1
Aug-21	0	0	1	0	1	0	2
Sep-21	0	0	0	0	1	0	1
Oct-21	0	0	1	0	0	0	1
Nov-21	0	1	1	0	0	0	2
Dec-21	0	0	3	0	1	0	4
Total	5	7	21	4	8	0	45
Mean	0.4	0.6	1.8	0.3	0.7	0.0	3.8
%	11.1	15.6	46.7	8.9	17.8	0.0	100.0
#11							
Date	None	P+	P	Neu	N	N+	Total
Jan-22	0	0	3	0	0	0	3
Feb-22	1	0	1	1	0	0	3
Mar-22	0	0	2	1	0	1	4
Apr-22	0	0	1	1	0	0	2
May-22	0	0	1	0	0	0	1
Total	1	0	8	3	0	1	13
Mean	0.2	0.0	1.6	0.6	0.0	0.2	2.6
%	7.7	0.0	61.5	23.1	0.0	7.7	0.0

Appendix 7 – 10: Breakdown of the sentiment analysis result of the reviews from Glucose Buddy Diabetes Tracker shown in months.

#1	Carb Manager						
Date	None	P+	P	Neu	N	N+	Total
1-Sep-2018	0	0	1	1	0	0	2
1-Oct-2018	0	0	4	0	2	0	6
1-Nov-2018	0	0	6	0	0	0	6
1-Dec-2018	0	0	4	0	0	0	4
Total	0	0	15	1	2	0	18
Mean	0.0	0.0	3.8	0.3	0.5	0.0	4.5
%	0.0	0.0	83.3	5.6	11.1	0.0	100.0
#2							
Date	None	P+	P	Neu	N	N+	Total
1-Jan-2019	0	1	12	4	2	0	19
1-Feb-2019	0	0	6	4	1	0	11
1-Mar-2019	0	0	9	2	0	0	11
1-Apr-2019	0	0	8	0	0	0	8
1-May-2019	0	0	9	1	4	0	14
1-Jun-2019	0	2	5	1	0	0	8
1-Jul-2019	0	3	11	2	2	0	18
Aug-19	0	0	6	1	1	0	8
Sep-19	0	0	17	4	3	0	24
1-Oct-2019	0	4	12	1	3	0	20
Nov-19	0	0	9	1	0	0	10
1-Dec-2019	0	1	7	0	0	0	8
Total	0	11	111	21	16	0	159
Mean	0.0	0.9	9.3	1.8	1.3	0.0	13.3
%	0.0	6.9	69.8	13.2	10.1	0.0	100.0
#3							
Date	None	P+	P	Neu	N	N+	Total
1-Jan-2020	0	1	20	0	0	0	21
1-Feb-2020	0	3	9	2	2	0	16
1-Mar-2020	0	1	10	1	1	0	13
Apr-20	0	0	2	2	1	0	5

1-May-2020	0	2	9	4	1	0	16
1-Jun-2020	0	2	9	3	1	0	15
1-Jul-2020	0	1	11	1	1	0	14
1-Aug-2020	0	0	5	1	1	0	7
1-Sep-2020	0	2	5	2	1	0	10
1-Oct-2020	0	0	2	2	0	0	4
1-Nov-2020	0	0	3	0	0	0	3
1-Dec-2020	0	0	3	0	0	0	3
Total	0	12	88	18	9	0	127
Mean	0.0	1.0	7.3	1.5	0.8	0.0	10.6
%	0.0	9.4	69.3	14.2	7.1	0.0	100.0
#4							
Date	None	P+	P	Neu	N	N+	Total
1-Jan-2021	0	3	12	3	2	0	20
1-Feb-2021	0	1	35	25	28	1	90
1-Mar-2021	0	0	11	5	2	0	18
1-Apr-2021	0	1	2	2	2	0	7
1-May-2021	0	1	5	1	1	0	8
1-Jun-2021	0	0	1	0	0	0	1
1-Jul-2021	0	1	3	0	0	0	4
1-Aug-2021	0	0	0	1	0	0	1
1-Oct-2021	0	0	2	0	0	0	2
1-Nov-2021	0	0	1	0	0	0	1
1-Dec-2021	0	1	0	0	1	0	2
Total	0	8	72	37	36	1	154
Mean	0.0	0.7	6.5	3.4	3.3	0.1	14.0
%	0.0	5.2	46.8	24.0	23.4	0.6	100.0
#5							
Date	None	P+	P	Neu	N	N+	Total

1-Jan-2022	0	1	6	1	2	1	11
1-Feb-2022	1	1	5	2	1	0	10
1-Mar-2022	0	1	0	1	0	1	3
1-Apr-2022	0	9	7	0	0	0	16
1-May-2022	0	0	1	0	0	0	1
Total	1	12	19	4	3	2	41
Mean	0.2	2.4	3.8	0.8	0.6	0.4	8.2
%	2.4	29.3	46.3	9.8	7.3	4.9	100.0

Appendix 11 – 13: Breakdown of the sentiment analysis result of the reviews from Carb Manager-Keto Diet tracker shown in months.

Supplementary Materials

1. Research design
2. 37 Diabetes apps_Digital Health Score Card_Selection
3. 9 Selected Apps using Digital Health Score Card selection Criteria 1
4. Result- Interview_questions_Percentage Score
5. Content Analysis using PPM