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Attention-Preserving Technology

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Abstract

Smartphone overuse and internet addiction is strongly correlated with a sharp rise in mental health problems, reduced productivity and increased suicide rates. The applications responsible leverage techniques from behavioural science to appeal to our base human natures, causing us to form unconscious habits which lead to increased usage. This greatly detracts from an individual's productivity and ability to focus on difficult tasks.

Many attempts have been made to develop technologies which help individuals reduce these effects in the form of well-being apps. The most effective well-being apps aim to use the same techniques from behavioural science used to hook users to reverse their own effects. However, even these applications are outclassed by their opposites, which are developed by billion-dollar corporations with endless funding and developer man-hours. This project seeks to continue the work of one such well-being app, closing the gap in product quality and feature offerings by leveraging recent advancements in application development methods.

On top of enhancing the original product and its applications in behavioural rehabilitation with new features, the resulting work facilitates developer on-boarding, reduces development time and implements analytical methods for developers to quantitatively assess how effective new features are at helping users improve their focus and productivity.

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- My tight support circle of friends, whom without the guidance of I would have been lost in trying to navigate the process of building such an ambitious product within the short time span of 6 months.

Dedication

This work is dedicated to all my fellow procrastinators who set out on a a productive day only to lose time to an unplanned YouTube binge. It happens to us all, and we owe it to ourselves to be aware of how the subtle ministrations of powerful organisations are designed to influence our lifestyles for their profit.

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Chapter 1

Introduction

1.1 Motivation

One does not need to quote scientific resources to know that the smartphone has been one of the most beneficial additions to modern society. The smartphone and the rich array of features it brings has changed the way many industries operate and increased speed of communication and efficiency. Banks utility companies no longer need to waste resources sending letters, colleagues can have video conferences at the drop of a hat, friends and family are just a message away.

However, some of the features that bring us such joy are the very same features showing recently to have a very detrimental effect in some users. Social media, emails and games are a constant distraction that exist on the very same device that is used for work and productivity, be it a smartphone or computer. There is much compelling scientific literature suggesting that the overuse of smartphones and the effects of its addictive applications is highly correlated to increased levels of sleep disorders, depression, anxiety and lower life satisfaction [1, 2, 3].

In this report a particular focus is given to the negative effects it has on the individual's attention capacity, motivation and focus. While some references will be made to extreme cases of highly-addicted audiences, the general demographic under study is the average adult, ranging from college students to working professionals.

1.1.1 Problem Statement

The presence of a smartphone or otherwise connected device has shown to have adverse effects on one's productivity and ability to stay focused [4]. This is especially so for individuals whose work involves many hours at at desk, working closely with a connected device, who are unable to decouple their personal devices from doubling-up as a productivity and communication tool for work.

This digital dependence requires the individual to always exercise some level of self-restraint, to prevent distraction from the priority task at hand, and its existence not at all coincidental. This report will show that the most successful modern smartphone applications are addictive by design and have very successfully secured a place for themselves in their users' lifestyles. The user is therefore, without external education and intervention, quite effectively helpless to identify and remedy the negative effects of smartphone use that have crept into their lifestyle.

1.1.2 User Attention as a Commodity

Social media and gaming applications (henceforth abbreviated as "apps") generate profits by retaining the attention of a user. Social media apps might monetize this by generating advertising revenue off of a user's screen time, or offer the user additional premium features requiring an in-app transaction to unlock.

Gaming apps have evolved to follow this model of monetizing continued user engagement: games in the early 2000's delivered a full product on an upfront purchase, seeking to deliver an experience that would encourage users to buy a sequel, but modern games now attempt to monetize continued user playtime by offering "microtransactions" in the form of in-game cosmetics or bonuses on top of the base game purchase.

As of June 2020, of the 5 companies to have ever been valued over a trillion dollars, 4 of them are technology companies that profit off of user engagement with their products: Apple ($1568b), Microsoft($1505b), Amazon($1337b) and Google($953b), leaving the winning business models

of the decade before such as Walmart($337b) and Johnson & Johnson($366b) in the dust [5]. Even Facebook($629b), whose business revenues are almost purely from monetizing user attention, easily doubles the value of the winning business models of the past.

Twitter (a social media company whose revenue comes primarily from advertising) even goes so far as toting the metric of "monetizable daily active users" (mDAU) in investor press conferences [6], referring to users which the company may show ads to. Investors of such business models focus so heavily on such metrics that, despite beating traditional financial health indicators (such as earnings estimates) by a sound margin in the third fiscal quarter of 2020, Twitter lost 20% of its stock value in a single day simply on the announcement that they had only gained 1 million new users instead of the projected 9 million [7] [6].

Therefore, the new hot commodity of the 21st century is no longer gold, silver or oil, but user attention. The attention, engagement and growth of an app's user base is so lucrative for these companies that they have completely changed how their business models are evaluated and priced.

1.1.3 Addictive App Design

Social media and gaming apps are therefore carefully designed in line with key concepts from behavioural science to be highly addictive, aiming to capture the user's attention and keep them coming back to interact with the application. This is loosely referred to in the industry as a user's level of "engagement" within the application. To increase and retain user engagement, techniques best described as "addictive software design" [8] are employed, including but not limited to:

- Variable rewards, as in gambling slot machines, maintaining an element of unpredictable positive reinforcement that keeps users coming back for more [8].
- "Bottomless" content with infinitely scrolling lists, experimentally proven to increase consumption [8].

- Ease of use and consistent user-interface elements across apps, allowing users to conveniently feel a sense of familarity when accessing their apps across all platforms (PC, smartphone, tablets and wearables).

Such mechanisms are deliberately crafted to appeal to the primitive parts of the brain responsible for unconscious habitual compliance (the limbic system), rather than those associated with rational, forward and deliberate thought (the prefrontal cortex). What this results in is a subtle shift in the tendencies of an individual to prefer comfortable compliance over exercising motivated choice. This tendency to act on habit and impulse is very natural for humans. We will see later in greater detail just how these apps exploit and reinforce this tendency to a point which can be extremely destructive.

With the onset of COVID-19 and the rise of the remote workplace, the line between work and play has grown even more vague. Individuals report higher screen time and video game participation which has been correlated to decreased mental health [9]. Smartphones and computers are key pieces of technology that are essential for connectivity and productivity in the age of remote work. The devices themselves do not pose a problem, but the access they give users to the attention-grabbing applications they contain have significant effects on the individual's ability to remain focused at work. The exercise of willpower alone, while possibly yielding some results in the short term, is not the solution to the problem.

1.1.4 Present Solutions

Therefore, many efforts have been made in the fields of neuroscience and psychology to raise awareness of the dangers of digital addiction. Similar addiction-based problems such as gambling and drug use may employ a "cold-turkey" approach, but depriving a modern worker of a smartphone and computer almost completely robs them of function in today's digital age. One approach to remedy device overuse is, paradoxically, the use of so-called well-being apps, which each attempt to address problems caused by internet addiction and overuse.

There are many more well-explored examples of insidious software design and behavioural

manipulation to exacerbate internet overuse [10], but the arguments proposed so far sufficiently motivate the creation of a solution that does not require the complete abstinence of smart-device usage.

Many examples of so-called well-being apps have been made, in a paradoxical attempt to design apps that would enhance users' productivity or state of mental health. However, [10] highlights that the such apps do not employ the same behavioural "hooks" that social media and gaming apps use. They often yield a short period of initial use, propelled by motivation, and then fall out of favour of their users within a few months.

Therefore, the work previously done in [10] proposes the concept of attention-preserving technology, which leverages the same behavioural science and software engineering techniques from addictive apps to help users stop using them and reverse their detrimental effects. The authors also produced a proof-of-concept: a well-being app called Sage. In summary, their work uses the development of Sage to highlight the failings of the well-being apps that came before it, proposing a set of design principles for future effective attention-preserving app design.

The Sage application helps users regain their focus and productivity through task and time-tracking features. However, given the short development time, it currently exists only as a minimal Android application with limited functionality. Despite this, an initial round of evaluation on the alpha release yielded positive reviews from testers, claiming that it improved their awareness of their own productivity and that they would continue using the application.

1.2 Objectives

The work documented in this report thus seeks to extend Sage with the following objectives:

- Engineering objective: Re-implementing the code base with methods that would be more suitable for lean development teams to continue their work, as well as adding infrastructure for quantifiable measurement of how well the application achieves its objective.

- Paradoxical social objective: Since Sage did not get a lot of development time and only implemented basic features, this project seeks to further explore how to further leverage the technologies and methods that cause the problem of digital addiction to reverse the problem.

- Application objective: Creating a product that may prove useful in prevention and rehabilitation of attention deterioration as a result of device overuse. This could even see use as a commercial product for companies wanting to help their employees improve their focus at work.

In summary, this run of the project aims to improve the current implementation of Sage. The application will be made available to a much larger user base by re-implementing the code base using cross-platform development frameworks. The user interface is then to be given a complete overhaul to improve the smoothness of the user experience and increase user engagement. More features will be proposed and implemented. Finally, an attempt will be made to create and implement quantitative evaluation methodologies that allow the product team to identify which features are most effective at helping users improve productivity and reduce screen time.

Chapter 2

Background

With the goals and objectives of the project clearly laid out, it is now necessary to explore the factors which drive digital dependence. This chapter explores the concepts in biology and neuroscience which cause "hooked" users to become unfocused and unproductive despite their best efforts to do otherwise. It will then highlight a few clear examples of how the design of modern apps leverage these concepts and then offer a design and implementation plan that

2.1 Biology Primer

To develop an app to fix the problem of attention deficiency, a short exploration into the mechanics of attention preservation is necessary. Within this scope, our focus will be on two different parts of the brain: the limbic system and the prefrontal cortex.

2.1.1 The Limbic System

The Limbic System carries out many functions that are considered "primal urges". Emotional responses to food, smell, social cognition, emotional memory, sexual behaviour and most importantly for this context, addiction and motivation [11]. All these functions can be summarised and grouped by one common concern: self and species preservation.

The limbic system (henceforth referred to as the "chimp"), is adept at remembering emotional responses to previously experienced situations and inducing the optimal response for self-preservation, should it find itself in a similar one. These responses can be associated with negative emotions, such as the fear one experiences when spotting a predator, or positive, such as the satisfaction and drive upon finding a food source. This is a gross over-simplification of the capabilities of the limbic system, but the message is clear: it is the part of the brain responsible for inducing impulses that it deems will result in the highest chances of survival and comfort.

However, with respect to self-control and achieving one's long term goals, this may be undesirable. The stress hormone (cortisol) produced when working under tight deadlines with complex problems is not unlike that produced in life-or-death situations in the wild. The chimp has no way of differentiating this and therefore the stress response induced by work is often registered as an existential threat, which encourages impulses of procrastination or indulging in escapism as part of a "flight" response.

2.1.2 The Prefrontal Cortex

The Prefrontal Cortex (PFC) is the part of the brain largely associated with conscious thought and rational self-control. An extremely well-cited study by Miller and Cohen concluded that in general, actions that require critical thought against our base instincts always involve the engagement of the PFC, and that test subjects with PFC impairment performed poorer on such tasks [12]. One such example was the sorting of cards by the colour verbally printed on them, even when the card itself was another colour (e.g. a blue card with the word "red" printed on it would be classified as red).

One prevailing theory is therefore that the PFC and the limbic system are often at odds in tasks involving self-regulation [13] and that successful self-control is a balancing equation of the strength of so-called "bottom-up" impulses and "top-down" conscious thought. This sets the stage for our narrative: that the "chimp" within us and the "human" are always at odds when it comes to work and procrastination. While the PFC may wish to act in favour of our

long-term goals, it often loses to the "chimp" and we are left with only a running commentary on our actions, despite our best wishes to do otherwise.

2.2 Self-regulatory Failure

Resisting the urge to check one's phone or play video games is a prime modern example of self-regulatory failure that reflects much in common with addiction-like behaviour in dieters, smokers and substance abusers. App-fueled procrastination may not be as lethal as substance abuse or obesity, but there nonetheless exists a very slippery slope into internet addiction that may ensnare the average person. Heatherton and Wagner elaborate in [13] that there are a few common causes for self-regulatory failure, which can be separated into two categories. "Top-down" factors are associated with reduced capacity or strength of conscious self-control such as negative moods and self-regulatory resource depletion. "Bottom-up" methods refer to unconscious or natural impulses such as cue exposure or lapse-activated consumption.

2.2.1 Resource Depletion & the Strength Model of Self-Control

Baumeister and Heatherton [14] initially proposed in 1996 that conscious self-control against one's impulses draws from a global resource pool that depletes as one uses it further. Since then, many studies have released results in support of this hypothesis. The strength model by construction dictates that it is possible to exhaust one's self-control and must be replenished like any other resource.

This suggests that as long as a distracting alternate stimulus is present, self-regulatory failure is not a question of "if", but "when". For traditional office work settings, this effect is ameliorated by the social norms enforced by the office culture. However, for a person working from home, the distraction unfortunately exists on the same device that enables productivity and there is no one else around to keep the chimp in check.

2.2.2 Cue Exposure

A cue in this context is defined as a piece of sensory stimulus which has an association to a certain consumption-related behaviour. The smell of food for a dieter, the sight of a beer for a heavy drinker. Cues have been shown to increase cravings, draw attention and increase likelihood of consumption [15]. Furthermore, multiple studies have shown that individuals are often unaware of how cues affect them on a conscious level[16], and so it becomes difficult for a struggling individual to pinpoint what it is exactly that causes their self-control to lapse.

The first example of addictive software engineering is the push-notification, one of the core tools of user-experience (UX) design. The premise seems simple: software engineers needed a way of bringing a user's attention to key information. This is not a "new" phenomenon, as pagers and message alerts have been around for as long as phones have existed. However, the graphical interface of the smartphone takes this to a new level. The modern push notification engages many senses: a kinetic vibration, an audio alert and a visual alert window.

Both Android and iOS have robust application programming interfaces (APIs) that enable developers to exercise a very high level of control over how their app sends and handles notifications [17]. In the example of a social media message from a friend, this allows for extremely alluring design: an avatar of the friend and a short preview of the incoming message. Users are even empowered to make the experience of receiving a notification as enjoyable for themselves as possible. Facebook Messenger allows users to set nicknames for their friends. Most phones allow users to set specific alert sounds on a per-contact basis, allowing a user to know from audio perception alone who they are receiving a message from. While this feature feels like one that helps the user "filter out the noise", one might argue that it in fact facilitates distraction, by allowing the user to have a stronger, more focused response to a self-set cue.

Cue exposure need not even be as explicit as a push notification. The experience of using a social media app or playing a game is extremely pleasurable. Beautiful colour palettes, high-resolution artwork and buttery-smooth animations are a staple in successful apps. All these factors enable the "chimp" to register a positive emotional response to act of phone use.

Therefore, the very presence of the phone is a form of cue exposure that constantly forces the user to exercise self-restraint.

2.2.3 Lapse-activated Consumption

A 1975 study showed that the consumption of a small amount of an addictive substance (in this case, a milkshake on a test audience of dieters) paradoxically caused dieters to consume more food afterwards, in contrast to the control group of non-dieters who ate less [18]. The exact reason as to why this phenomenon occurs is not fully clear, but the implications of its existence are. Picking up one's phone for a short break from work can often snowball into a longer-than-intended session of scrolling social media. Playing "just one round" of a game often ends up being anything but. We will explore in later sections what mechanisms are in place that potentially cause such activities to be so difficult to quit.

2.2.4 Consequences of Distraction

Levy and colleagues showed that not only is the occurence of a disturbance a problem, but the "richness" of that disturbance was also detrimental to subjects' performance on cognitive tasks [19].

2.2.5 Motivation and Persistence

We have seen so far that the outcome of a self-restraint task comes down to whether the strength of bottom-up impulses exceeds that of our top-down intentions. Most of the time, this tends to be the case. Having explored all the ways in which self-control can fail due to how strong our in-built tendencies are, perhaps then there is a way in which we may use these natural tendencies to our advantage, or at least increase the strength of top-down control.

2.2.6 Strengthening Self-control

Muraven, Baumeister and colleagues conducted a study in which subjects performed consistent amounts of self-enforced exercise over two weeks. While this caused slightly decreased self-control capability on the day, this "strength drain" diminished rapidly by the day and resulted in increased success in other completely unrelated self-restraint tasks [20]. Muraven took these results again in a later study and found that "smokers who squeezed a handgrip or avoided sweets for two weeks before quitting cigarettes remained abstinent longer and had fewer lapses overall as compared to smokers who practiced tasks that did not require self-control" [21].

These studies, and many others like it, strongly support the previously mentioned strength model of self-control. Metaphorically, self-control behaves very much like a muscle: its capabilities are slight diminished following immediate use and while it is possible to fatigue it significantly, it is also possible to increase its capabilities with consistent amounts of progressive load.

2.2.7 Impairing Impulses

Cinciripini and colleagues investigated the effects of schedules and gradual consumption reduction in smoking cessation. Participants were all given uniform education on the psychology of nicotine addiction and methods of coping [22]. Control over consumption was exercised in two forms: scheduling, where participants were allowed to smoke at designated and progressively lengthened intervals, and reduction, where consumption was reduced by a third of the subject's baseline consumption each week. The scheduled and reduced group unsurprisingly performed best, with the greatest reduction in mean cigarette consumption and reduced frequency of urges and severity of withdrawal symptoms. Reduction alone contributed most to the reduction of urge frequency, and scheduling seemed to have an effect on mean consumption.

Results from studies such as these suggest that the controlled appeasement of urges may be a key factor in helping to diminish the effects of bottom-up impulses and serve as a basis for productivity schedules such as the pomodoro technique.

2.3 Addictive Design

The principles of behavioural science examined so far dictate that a successful well-being app therefore has to not only help the user form healthy habits that help them avoid self-regulation pitfalls, but offer new "hooks" to help to keep their inner chimp from becoming overly restless.

2.3.1 Social Media

Social media offers novelty at every turn, with variable rewards

2.4 Gaming

Gaming, on the other hand, are capable of offering a dense, fast-paced, highly engaging experience.

2.5 The Existing Sage Application

2.5.1 Functional overview

After granting the app permissions for notification access in an onboarding sequence, the app starts up and offers its core functionality: a task list. Users may create and edit tasks. Each task may be recurring daily, and may block notifications. Users may then at any time start working on a task, triggering a running timer which may block all incoming notifications while active. A task can be completed, or returned to any time later with a break. All this activity is stored within the client and can be displayed to the user through graphs as a form of feedback on their productivity.

2.5.2 Limiting issues

While the work done so far is an admirable starting effort, there are many potential points of improvement from a user-experience perspective. There are several issues and limiting features with the current implementation of Sage, from both a UX design and software engineering perspective:

Design & User Experience

- The selected colour palette is rather dull, with no possible customisation on behalf of the user.
- All the assets and images are static, with no animation or movement to drive user engagement.
- Sizing of interactive elements is not well-standardised, and in most cases are oversized.

Software Engineering

- The notification blocking feature is faulty. Certain edge cases allow notifications to still slip through.
- Currently implemented only as an Android app, no extensibility to iOS, desktop or mobile web users.
- Completely local: no data backups or export, no online cloud synchronisation.

2.6 Project (Re-)specification

Modern individuals are unable to focus and stay productive for a multitude of reasons. This project seeks to solve that problem by creating a user experience that leverages the concepts explored so far, such that less deliberate exercise of self-discipline is necessary for the user to remain on-task.

Proposing a re-implementation software project naturally begs the following questions: - What advantages will the effort yield, and is it worth the effort? - Will it perform as before, or are there be any compromises as a result of the move?

As such, some initial research had to be conducted to address the concerns. Studying the existing codebase and Android developer documentation

As in any other software engineering problem, the first step is to gather an initial list of requirements that will form the specification of what the final product must achieve.

The re-implementation of the Sage application thus should fulfill the following set of requirements in its MVP:

Functional Requirements

- Re-implement the full feature set of the existing application.
- Fix notification blocking functionality with the use of *Do not Disturb* mode, instead of the current implementation.
- Add online cloud storage and synchronisation of user data.

Non-functional Requirements

- Must be performant without excessive jank, jitter or loading delay.
- In the event of a crash, the application should recover gracefully and inform the user of any inconsistencies in their data caused by the crash (interrupting a focus period, etc).

2.7 Implementation Plan

2.7.1 Software Development Practices

An excellent starting point for planning this project is to follow the principles laid out in agile software development. Agility is a concept often used to in business strategy and operation,

referring to an organisation's ability to adapt to quickly changing business demands and put themselves in the most competitive position possible. This concept has naturally spread to software development practices and there now exist frameworks for teams to follow such as Scrum, lean software development and Kanban.

2.7.2 Time Management

There are 3 key members in this project team in this interim phase: the part-time solo developer, the supervisor and a consultant who doubles as the client. Given the timing and nature of term-time work, the structure of development cycles must be flexible to accomodate for unforeseen workload variance on behalf of the developer or consultant. Core members are only available on a part-time basis until the summer term,

We therefore structure work into variable 2 or 1-week sprints, taking after agile software development practices instead of a typical waterfall Gantt chart structure.

Each

2.7.3 Plan of Deliverables

2.8 Evaluation Plan

Instead of the typical academic approach of conducting individual user studies on a select sample, this app hopes to build feedback in to the app as part of the user experience. The app is thus hosted on a cloud provided with a generous "free tier" allowance, allowing us to experiment with a sizeable user base of what we estimate to be up to 500 users before cloud computing costs actually start to kick in.

For this study, the concerns are not to develop the world's best-selling productivity app or to gain traction with a massive user base. This preliminary phase of the project is to find a way to measurably determine how effectively the Sage platform does its job of helping users stay on

task. The refinement, re-selection and validity of these metrics will have to be determined as part of future work when the app is released in beta to the test audience. As an example, we may wish to measure a given user's productivity on a day-to-day basis by capturing a "productive window" in which a user continues to execute tasks without a significant (15 minute) disruption.

The app will be released to students in Imperial College London through the Android and iOS distribution channels, with its intentions clearly stated in both publicity efforts and as part of the in-app onboarding process. We hope to complete development on the alpha release in time for the Easter holiday, when students will be focusing on studying for exams.

2.9 Ethical, Legal and Safety Plan

This project has no actionable safety concerns, since there is no physical product in which the user might harm themselves with. The primary concerns are with the use of third-party intellectual property and the safe and compliant use of user data for analytics and product improvement.

2.9.1 Software Licensing

This project will leverage the use of open-source software libraries and frameworks, the largest example of which is React Native. Open-source, by definition, allows the unrestricted redistribution and modification of a given piece of software for any purpose. As a secondary precaution, all packages used will be derived from the Node Package Manager (NPM) registry, which effectively serves as a central distribution point of open source packages pertaining to the javascript ecosystem (in which this project resides).

Most, if not all packages registered on NPM have an open-source approved license selected for their project. That is, a license which is in accordance with the open-source philosophy of freely useable, modifiable and shareable code. The list can be found at the open source initiative organisational website. Should the exceptional case arise in which a package is used which does

not use one of these licenses, it will be explicitly justified and disclosed in its implementation documentation. However, this should technically never arise.

2.9.2 User Data Usage and Compliance

This study will use the General Data Protection Regulation (GDPR) as a basis of rules to follow in the ethical collection and use of user data. The following subsections will outline the parts of the GDPR deemed relevant to the nature of data used in this study, and perform a risk assessment of where grey areas may occur.

In the interest of brevity, the GDPR checklist can be found here. In addition to having completed this checklist, the Sage application will adopt the following policies for the collection of user data:

- Users will be explicitly informed during the onboarding process what data we collect for evaluation metrics and how we will use it. The usage of the app requires the user to consent to this, as there is otherwise no point in us offering the service which could otherwise incur cloud computing costs.
- The application does not capture any data defined by the GDPR as "personal", except for the user's email. Evaluation metrics, while potentially changing over the course of the project, should not allow the de-anonymisation of a given user.
- Data will be sent and stored using secure channels, using third-party GDPR compliant vendors where applicable.
- In the unlikely event of a data leak, users will be immediately informed via email what was leaked. However, none of this data should be particularly harmful to a user even if this should happen.
- Users may at any time erase all their usage data within the settings menu.

Chapter 3

Engineering Rationale

This chapter reviews and justifies the choice of software used in the stack for this project.

3.1 Cross-Platform Frameworks

A long standing problem in the development of mobile applications has been that of having to maintain multiple codebases in order to increase user reach. Especially since different platforms almost always use completely different workflows and programming languages, this means having to employ multiple teams just to maintain separate codebases, leading to features being rolled out on one platform before another, or an inconsistent user experience between both platforms.

Cross-platform development seeks to solve this problem, often by creating a workflow in a given language which may then be transpiled into native platform code. While this solves the aforementioned problem, it also creates problems of its own. Cross-platform frameworks usually offer a reduced set of features compared to their native counterparts, since they effectively have to duplicate the API that the native platform exposes using different language semantics, which may not even be possible in some cases.

Despite this, cross-platform frameworks have found their niche in helping small teams of de-

velopers bring a concept to market quickly. It is for this reason that this project will use a cross-platform framework in order to bring the product to iOS in a way that is extensible for future work, especially since no feature in this app requires the complexity that native development offers. The following subsections will evaluate the current two most popular choices of cross-platform frameworks.

3.1.1 Flutter

Flutter is a recent framework released in 2017 by Google, aiming to provide a set of out-of-the-box interface elements to enable quick development of beautiful user interfaces. As of the time of writing, Flutter has full support for iOS 14, Android 11, macOS, Windows and web [23].

However, the primary criticism of Flutter is not only its age, but that it runs in Dart, another language made by Google. This means that not as much libraries and packages for flutter are limited, which means likely having to write much more first-hand code and less stable releases of libraries.

3.1.2 React Native

React Native was released by Facebook in 2014 and continues to be one of the most developed open source projects on Github (alongside Flutter). It builds off of the Model-View-Update architecture originally implemented by React and shares many domain-specific semantics. It runs on JavaScript, which is by a large margin the world's most popular programming language [24] and therefore has full access to the open-source library distribution channels that it offers. This mean stable support on well-developed and community endorsed packages that enforce a standardised implementation of many common features that developers use.

The result is a smooth cross-platform experience that offers close-to-native performance and a fully-functioning native bridge to give developers full flexibility in writing native code where necessary. The success of React Native has attracted many reputable companies to build their platforms with it, such as Walmart, UberEats, Bloomberg and Pinterest [25].

3.1.3 Comparison

The primary cause of concern regarding framework choice in this project is which one best enables speed of development. This project is scoped, designed and executed by a single engineer. The scope proposed so far is usually the work of multiple full-time software engineering teams. The age and reduced developer community size for Flutter is therefore a deal-breaker in this case. The NPM registry for JavaScript currently boasts over 1 million packages in comparison to its Flutter equivalent, pub.dev which currently has around 21000. Developer documentation and community FAQ pages are also likely to have answers to issues on JavaScript rather than Dart, which means much more time can be spent focusing on higher level application design instead of "re-inventing the wheel".

3.2 Cloud Hosting Vendors

Based on requirements so far, the application will also require a back-end with a database for persistent storage of user data. This, along with what will potentially be the web version of the app, will require hosting on a server. This section briefly evaluates a selection of popular cloud service vendors and how their offerings are relevant to the requirements of this project.

The offering of a Cloud-service provider can be thought of as the balance of two philosophies: "bare-metal" providers, and managed solutions. Bare-metal refers to the act of simply provisioning computing resources on a machine, the specifics of which are left up to the user to implement. The state-of-the-art nowadays would be for a developer to specify a containerised environment using a tool such as Docker or Kubernetes, effectively creating an isolated "container" which contains all the environmental requirements needed to run a desired program. A bare-metal service would then simply bill the developer based on pre-defined billing criteria such as CPU runtime, memory usage and network bandwidth consumption.

Managed solutions are built on top of the bare-metal philosophy. Cloud service providers may have specific offerings which deliver value to their customers in the form of pre-defined APIs

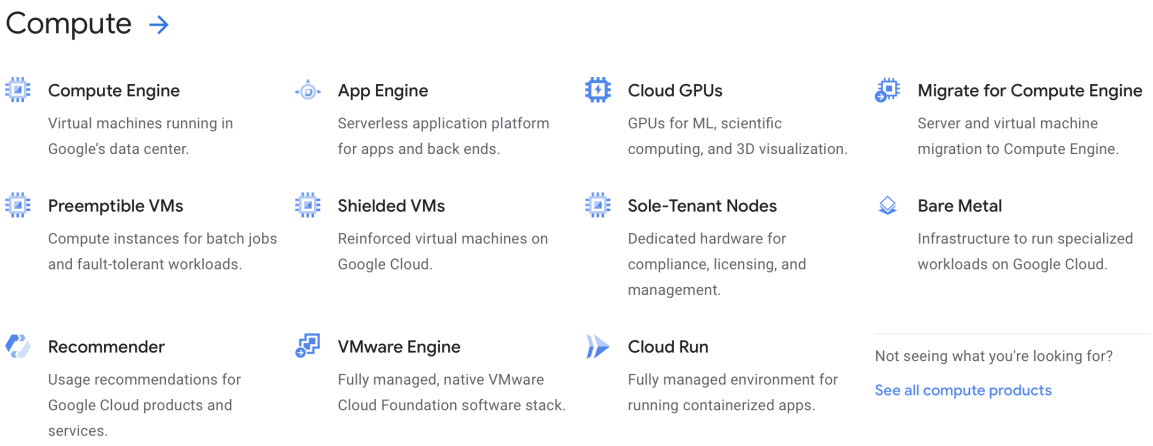

Figure 3.1: Google Cloud compute product offerings

which achieve a commonly desired functionality, such as user authentication. The market-leading solutions often provide a modular product selection that gives a developer a large degree of freedom to build suitable solution. One example of this is Google Cloud, which offers different degrees of control within its compute offerings, ranging from fully managed to completely bare metal.

3.2.1 Firebase

Firebase began as a startup that was later acquired by Google and now stands as one of the most popular backend-as-a-service platforms for developers looking to get small projects off of the ground. Firebase currently offers an unparalleled out-of-the-box offering for implementing safe user authentication, identity management, database and on-demand cloud compute.

However, all these benefits come at the cost: Firebase is closed-source and has vendor lock-in built into its design. Firebase is much more opinionated than the other back-end solutions that we have explored, in the following ways:

- Databases are accessed directly by clients instead of a back-end endpoint through the Firestore or Realtime Database APIs
- Firebase-provided databases are strictly non-relational.

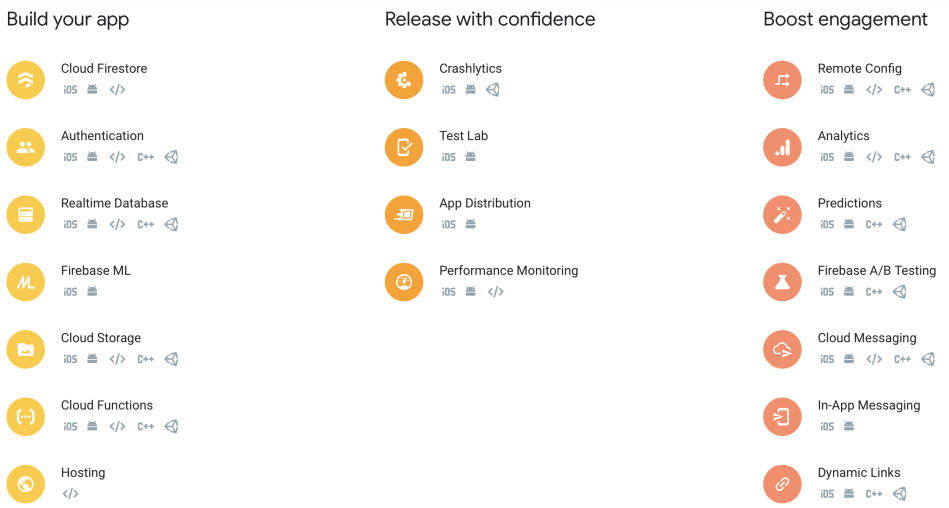

Figure 3.2: Firebase product offerings

- On-demand compute comes in the form of Firebase Cloud Functions, which is designed for small bursts of computation instead of long-running loops. The latter is still possible, but the resulting bill would be unfeasible.
- Cloud Functions currently only supports REST APIs and only supports a limited range of runtime environments [**?**].

Despite these, Firebase provides key functionality which may prove extremely valuable in continuing development for this project. Even if not implemented in this run of the project, Firebase offers out-of-the-box solutions for file storage, app crash analytics, search engine optimisation, A/B testing and even (limited) machine learning tasks. Therefore, it is undisputably the platform that will enable the fastest development of a workable product.

In summary, the features that it provides will service the needs of future development on this project for a long time to come. Even if it should scale beyond that point, there should be enough resources to facilitate a migration away from Firebase anyway.

Chapter 4

Implementation

4.1 Re-implementing the existing product

Chapter 5

Conclusion

5.1 Summary of Work Done

The essential functionalities of the existing app have been re-implemented, with major UI improvements for improved useability and a leaner user experience.

5.2 Applications

The application, if successful, could see uses in rehabilitation of

5.3 Future Work

The next steps in this project would be to start with user feedback cycles. At present, we do not expect enough users to be able to implement A/B testing. However, feedback will be built into the app and aggregated for weekly design reviews. The present goal is to have an MVP that implements goal setting, to-do lists and notification blocking up by the beginning of the Summer term, so that we might start collecting usage analytics from students who are studying for exams.

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