Imperial College London

Gamification elements in smoking cessation mobile apps and their effects on the self-efficacy and motivation to quit of smokers

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A thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy (PhD)

September 2021

Copyright Statement

Declaration of Originality

I declare that the work presented in this thesis is original and my own; any work that is not mine has been appropriately referenced. I acknowledge the support and guidance from my supervisors, Dr. Filippos Filippidis and Dr. Nikolaos Mastellos, to carry out the research that has been presented. Some of the work that is part of this thesis has been disseminated in peer-reviewed publications or conferences. The co-authors have contributed to the peer-reviewed publications, but the text, methods and analyses presented in these publications and the thesis are my own.

Publications (Appendix M)*:

1. Rajani NB, Weth D, Mastellos N, Filippidis FT. Adherence of popular smoking cessation mobile applications to evidence-based guidelines. *BMC Public Health.* 2019; 19 (1): 743. Available from: doi: 10.1186/s12889-019-7084-7.

2. Rajani NB, Weth D, Mastellos N, Filippidis FT. Use of gamification strategies and tactics in mobile applications for smoking cessation: a review of the UK mobile app market. *BMJ Open.* 2019; 9 (6): e027883. Available from: doi: 10.1136/bmjopen-2018-027883

3. Rajani NB, Mastellos N, Filippidis FT. Self-Efficacy and Motivation to Quit of Smokers Seeking to Quit: Quantitative Assessment of Smoking Cessation Mobile Apps. *JMIR mHealth and uHealth.* 2021; 9 (4): e25030. Available from: doi: 10.2196/25030 .

4. Rajani NB, Mastellos N, Filippidis FT. Impact of Gamification on the Self-Efficacy and Motivation to Quit of Smokers: Observational Study of Two Gamified Smoking Cessation Mobile Apps. *JMIR serious games.* 2021; 9 (2): e27290. Available from: doi: 10.2196/27290

*Publications are under my maiden name (Nikita Rajani)

Acknowledgements

First and foremost, I want to express deep gratitude to my supervisors Dr. Filippos Filippidis and Dr. Nikolaos Mastellos. I am greatly appreciative of their mentorship and guidance during each stage of my PhD. Their expertise and knowledge, prompt and thorough feedback, and reassurance have been very valuable. I have known Dr. Filippos Filippidis for 7 years and Dr. Nikolaos Mastellos for 6 years, and I can confidently say that my journey as a PhD candidate and generally as part of the Imperial College London community, was greatly shaped by their positive influence.

Second, my collaboration with the developers of the mobile apps Quit Genius and Kwit was integral for my research. I specifically want to thank Yousuf, Sarrah and Jamie from the Quit Genius team, and Geoffrey and Luza from the Kwit team. Thank you for providing the study's participants access to your apps, solving technical problems quickly, sharing in-app metrics and helping ensure that data collection was a smooth process.

Of course, this PhD thesis would not have been possible without the support from my family and friends. I want to thank my husband for always being there for me, enduring countless hours of me talking about my research, and providing insightful and constructive feedback. To my parents, brother and wider family – thank you for believing in me, helping me stay positive and always providing encouragement. I am very lucky and grateful for your unwavering love and support.

Finally, I would like to thank everyone that has crossed paths with me during my time at Imperial College London. Over the last 7 years, as a masters student, research assistant at the Department of Primary Care and Public Health and a PhD candidate, I have had the pleasure of working with incredible peers and colleagues. I want to thank you all for the support, laughter and inspiration.

Abstract

Background and Aim: Gamification can positively impact self-efficacy and motivation to quit, two vital factors associated with smoking cessation. Since it shares key components with behaviour change theories and is easily applicable to digital interventions, gamification has the potential of improving the effectiveness of mHealth solutions. However, the role of gamification in the context of smoking cessation and mHealth has been sparsely investigated. My research aims to examine gamification elements in smoking cessation mobile apps and quantitatively investigate their effects on the self-efficacy and motivation to quit of smokers seeking to quit.

Methods: A review of smoking cessation apps on the UK market assessed app adherence to treatment guidelines and incorporation of gamification. One of two mobile apps identified from the review were assigned to smokers seeking to quit for a 4-week long study. Linear and logistic regression models investigated the effects of gamification on self-efficacy, motivation to quit and smoking cessation. Pairwise Pearson correlations compared self-reported and in-app engagement data. Statistical significance for all models and tests was determined at the 5% (.05) level.

Results: Smoking cessation apps had low adherence to treatment guidelines and did not incorporate a high level of gamification. Compared to baseline, self-efficacy and motivation to quit statistically significantly increased after app use. Perceived engagement with overall gamification was associated with change in self-efficacy (β=3.35, 95% CI: 0.31 to 6.40) and motivation to quit (β=0.54, 95% CI: 0.15 to 0.94). Engagement with the steps/levels feature (based on self-reported and in-app data) was associated with change in self-efficacy and 7-day smoking cessation. Self-reported and in-app engagement data were positively moderately correlated.

Conclusion: Gamification in mobile apps can have positive effects on the self-efficacy and motivation to quit of smokers. The findings provide important insights for tobacco control policymakers, mobile app developers and smokers trying to quit.

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Abbreviations

1. Apps ..... Applications
2. COPD ..... Chronic Obstructive Pulmonary Disease
3. COVID-19 ..... Coronavirus Disease
4. CVD ..... Cardiovascular Disease
5. FCTC ..... Framework Convention on Tobacco Control
6. iOS ..... iPhone Operating System
7. mHealth ..... Mobile Health
8. MTQ ..... Motivation to Quit
9. NCSCT ..... National Centre for Smoking Cessation and Training
10. NHS ..... National Health Service
11. NICE ..... National Institute of Care and Excellence
12. NRT ..... Nicotine Replacement Therapy
13. PID ..... Patient Identification Number
13. RCT ..... Randomised Controlled Trial
14. SES ..... Socioeconomic Status
15. SEQ ..... Self-Efficacy
16. SEQ-12 ..... Smoking Self-Efficacy Questionnaire
17. SHS ..... Secondhand Smoke
18. SSS ..... Stop Smoking Services
19. SUS ..... System Usability Scale
20. TAM ..... Technology Acceptance Model
21. UK ..... United Kingdom
22. US ..... United States
23. WHO ..... World Health Organisation

Chapter One: Introduction

1.1 Background and Context

Although smoking prevalence in high-income countries such as the United Kingdom (UK) has fallen drastically over the past decade, smoking remains a major preventable cause of death and disability worldwide[1-2]. Despite the majority of smokers wanting and willing to quit, smoking cessation rates remain low in many countries[3-4]. In the UK specifically, long-term abstinence of 12 months was estimated to be approximately 8%[4]. Simultaneous to poor quitting rates, the number of people making quit attempts and accessing smoking cessation services has also been falling in the UK over the last few years[5-6]. Since engagement with smoking cessation services is strongly associated with higher quit rates[4], lower utilisation of such services is concerning. Consequently, it is important that research investigates interventions that can increase the likelihood of making quit attempts and successfully quitting whilst still being easily accessible and low-cost to those individuals seeking face-to-face assistance but are not willing or able to do so.

Behaviour change interventions, whether face-to-face or remote, often target the self-efficacy and motivation to quit of smokers as these factors are associated with successful cessation. According to Bandura (1977), self-efficacy is an individual's perceived confidence to perform a behaviour[7]. Several studies have established that high self-efficacy is positively associated with successfully quitting and a lower likelihood of relapsing during a given quit attempt[8-11]. Similarly, motivation is an internal process that initiates, guides and maintains goal-oriented behaviour. In the context of smoking-related studies, motivation to quit refers to an individual's readiness to change and determination to quit smoking[12]. Many studies in the literature have found that individuals with high motivation to quit had greater quitting success, particularly in the long-term[13-17].

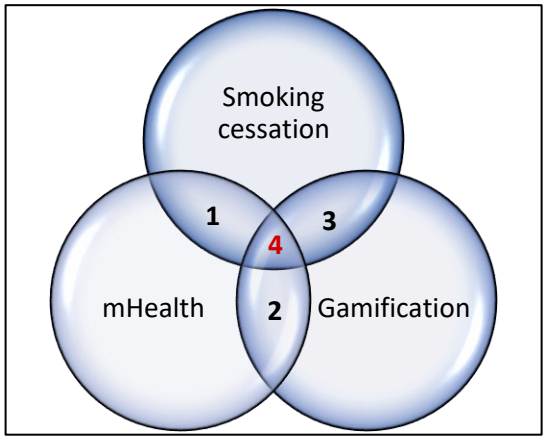
Among several methods found to enhance self-efficacy and motivation to quit, gamification is one that is relatively novel, understudied and continuously evolving. Gamification is defined as the use of game elements in a non-game context and it has been frequently recognised to positively influence confidence and motivation to drive health behaviour change[18-20]. Sharing

key elements with behaviour change theories and techniques has led to the increased application of gamification to health behaviour change interventions[21-22]. Moreover, due to its easy implementation to digital technologies, gamification has also frequently been incorporated into mobile application (app) based interventions. Whilst there is evidence that gamification can positively impact health and wellbeing, in the context of mobile health (mHealth) interventions, such as mobile apps, the research to date has primarily focused on physical activity and mental health[23]. Consequently, a need for research to explore the impact and use of gamification in mHealth solutions for other health behaviours, such as smoking cessation, has been identified and will be addressed in my thesis.

1.2 Rationale

The three main components of the research presented in this thesis are smoking cessation, mHealth and gamification (figure 1.1). To date, little attention has been paid to the role of gamification in mHealth solutions for smoking cessation.

Figure 1.1 Intersection of research fields



There are several studies in existing literature on smoking cessation interventions delivered via mHealth (overlap 1). Prior research has found evidence that mHealth interventions can increase the likelihood of quitting and remaining quit[24]. There is also significant research on mobile apps for smoking cessation but a large proportion is feasibility or pilot-testing research. Similarly, there are some studies that explore the use of gamification in the context of mHealth (overlap 2). However, many of these have concentrated on physical activity, mental health and chronic conditions such as diabetes. In general, there has also been a large focus on studying the development, design and usability of gamification in mHealth interventions, particularly in mobile apps[25-26]. Only a few studies examined the effects of gamification in the context of smoking cessation but not mHealth (overlap 3). Pløhn & Aalberg (2015) found positive effects of gamification as an important motivational factor to aid quitting among participants that engaged with a digital but not mHealth-based intervention[27]. Similar studies examined the impact of gamification in face-to-face interventions for other health behaviours, such as

consumption of fruits and vegetables[28]. Although not the case in the field of academia and education, gamification is often incorporated into digital rather than face-to-face interventions in the context of health behaviour change.

Despite the easy applicability of gamification to mHealth solutions, the largest gap identified in the literature falls within the intersection of all three subfields (overlap 4). The studies that do investigate gamified smoking cessation mobile apps focus on the development and usability of these apps[25-26,29]. There are only a handful of studies which examine the impact of gamification on either smoking cessation outcomes or factors associated with successful cessation. For example, El-Hilly et al. (2016) found promising results on the effect of gamification on the motivation and engagement of smokers within the context of mHealth[30]. Similarly, Tudor-Sfetea et al. (2018) examined gamification in smoking cessation mobile apps but concentrated primarily on the perception of and engagement with gamification rather than exploring the effects of gamification[31]. The few studies on gamified smoking cessation mobile apps suffer from small sample sizes, are frequently of qualitative nature and do not explore the influence of gamification on success factors for quitting.

Exploring the effects of gamification in smoking cessation interventions on cognitive factors could help increase our understanding on how quit rates can be improved. This could lead to a decrease in prevalence of chronic diseases and premature mortality. Moreover, due to the easy applicability of gamification in mHealth and the cost-effectiveness of mHealth solutions, understanding the usefulness and impact of remote interventions for smoking cessation would be valuable, particularly at a time when fewer people are accessing professional services to aid quitting. Consequently, the learnings of this thesis can contribute to a better understanding of gamification in smoking cessation apps and have important implications for smokers, mobile app developers, behaviour change specialists and tobacco control policymakers.

1.3 Research Aims and Objectives

To address the gap in the literature and build on existing knowledge of this infant subfield, the overall aim of my research is to explore the association between gamification and both

self-efficacy and motivation to quit among smokers seeking to quit smoking. More specifically, the primary and secondary objectives of my thesis are:

1.3.1 Primary Objectives

I. Explore the use of gamification in smoking cessation mobile apps available on the UK app market.

II. Investigate the impact of gamified smoking cessation mobile apps on the self-efficacy and motivation to quit of smokers seeking to quit smoking using self-reported and in-app data; this includes examining the effects of overall gamification and specific game elements on self-efficacy and motivation to quit.

III. Compare self-reported and in-app data on engagement with gamification elements in smoking cessation mobile apps.

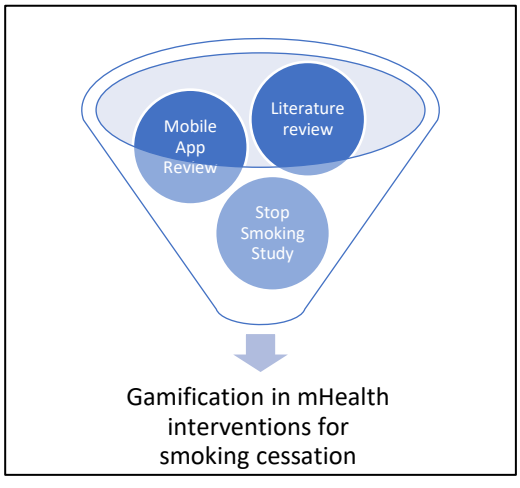
1.3.2 Secondary Objectives

I. Investigate the adherence of smoking cessation mobile apps on the UK app market to evidence-based smoking cessation guidelines.

II. Explore the impact of engagement with gamification features in mobile apps on smoking cessation outcomes.

1.4 Overview of Methodology

Figure 1.2 Three-step methodology



A three-step methodology was adopted to address the aims and objectives of this thesis (figure 1.2). First, research on smoking cessation, mHealth and gamification was thoroughly reviewed to gain a better understanding of the existing literature. Second, an up-to-date review of mobile apps for smoking cessation available on the UK app market was conducted. The third step of the methodology was the design and execution of an observational study, called the *Stop Smoking Study*. The study investigated the effects of two gamified smoking cessation mobile apps (identified by the mobile app review) on the self-efficacy and motivation to quit of smokers seeking to quit. The study collected and

analysed self-reported data from participants and in-app data shared by collaborating app developers.

1.5 Structure of Thesis

This research thesis is divided into six chapters. Following this introductory chapter, chapter two presents a thorough literature review of the main components of my thesis. It synthesises information on smoking and smoking cessation, and explores how self-efficacy and motivation to quit are defined, measured and related to smoking cessation. It also reviews how gamification is defined, operationalised and applied to mHealth. Lastly, the literature review critically evaluates existing studies on gamification in smoking cessation mobile apps. After the literature review, I address the first primary objective of my research in chapter three by presenting the objectives, methodology and results of a mobile app review of smoking cessation apps available on the UK app market. Chapter four addresses the second primary objective by presenting the main study of this thesis, the *Stop Smoking Study*. The aim of chapter four is to understand the effects of gamification on self-efficacy and motivation to quit using self-reported data. Building upon this, chapter five uses in-app data to further examine the effects of gamification on both self-efficacy and motivation to quit. Chapter five also addresses the third primary objective of this thesis by comparing and contrasting self-reported and in-app data associated with frequency of use of game elements. Finally, the sixth chapter of my thesis summarises the main findings of my research and discusses some of the key implications for research and practice.

1.6 Chapter Summary

This chapter introduces the research focus of my thesis on gamification in the context of smoking cessation and mHealth. It provides a summary of the general situation on smoking cessation and an overview of a gap identified in the literature regarding the lack of knowledge on gamification in mobile apps for smoking cessation. The chapter also presents the primary and secondary objectives of my thesis and an outline of a three-step methodology used to address these objectives. The methodology includes an in-depth examination of the existing literature, a review of mobile apps on the UK market and an observational study (Stop Smoking Study) examining the effects of gamification on the self-efficacy and motivation to quit of smokers seeking to quit.

Chapter Two: Literature Review

2.1 Introduction

Globally, smoking was attributed to almost eight million deaths and a loss of 200 million disability-adjusted life-years in 2019, making it a major modifiable risk factor driving death and disability[1-2]. Despite falling prevalence rates, there are more than a billion current smokers worldwide causing the tobacco epidemic to remain a critical public health priority that continues to pose a significant economic burden on national healthcare systems[2]. Whilst a majority of smokers want to quit smoking, successful cessation rates remain low[3,32-34]. To better understand how quitting rates can be improved, a large body of literature has investigated the determinants and factors influencing smoking cessation. Among several determinants, self-efficacy and motivation to quit have been found to increase the likelihood of making quit attempts and the odds of successfully quitting[8-11, 13-17]. Exploring methods to improve self-efficacy and motivation to quit could result in better quitting rates, and thereby reduce the prevalence of chronic diseases and premature mortality.

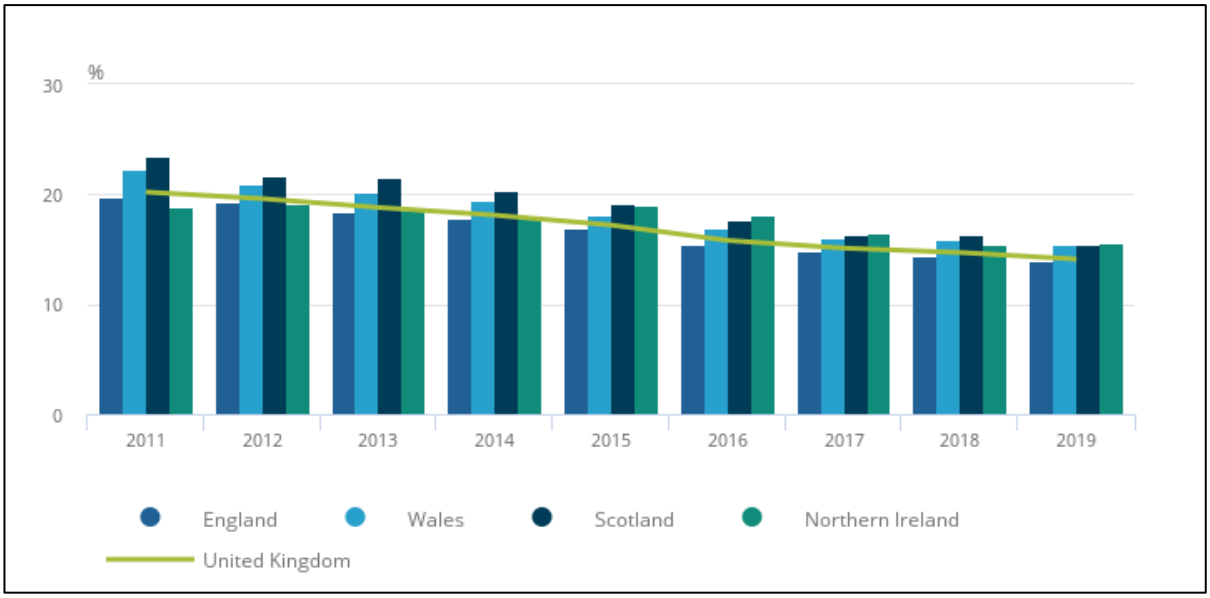
One novel and increasingly used strategy in the field of healthcare is gamification[18]. A systematic review examining the use of gamification in healthcare and wellbeing interventions found that gamification can positively impact psychological and behavioural health outcomes[23]. There is some evidence indicating that gamified interventions can have immersive effects on a user, leading to increased levels of motivation compared to non-gamified digital interventions[35]. Whilst preliminary research on gamification in the context of mHealth has shown positive results, existing literature has focused primarily on physical activity, mental health and chronic conditions such as diabetes[23]. To date, there have been few empirical investigations on the effects of gamification in mHealth solutions on vital success factors for smoking cessation, such as self-efficacy and motivation to quit. In order to provide a thorough and critical understanding of the key components that form the basis of this research and highlight a gap in the existing literature, this chapter covers the following topics: a) smoking, b) self-efficacy and motivation to quit, c) gamification and d) mHealth.

2.2 Smoking

2.2.1 Smoking Prevalence

The tobacco epidemic is a large and growing public health concern. Since cigarette smoking is the most common form of tobacco use globally, it is the central focus of this thesis. According to the latest global disease estimates, out of the eight million deaths attributed to smoking tobacco in 2019, approximately seven million were due to the direct consumption of tobacco and the remaining one million were associated with exposure to secondhand smoke[36]. Among the 1.1 billion smokers globally, 80% live in low and middle-income countries which also represent the regions of the world that have the highest burden and deaths attributed to tobacco-related illnesses[36]. Within the UK, population-based surveys show that approximately 14.1% of adults, equivalent to around 6.9 million people, smoked cigarettes in 2019[1]. Broken down to a national level, Northern Ireland has the highest prevalence of smoking overall (15.6%), followed by Wales (15.5%), Scotland (15.4%) and lastly England with the lowest prevalence of 14.1%. In the UK altogether, smoking prevalence is higher in men (15.9%) compared to women (12.5%) and this trend is consistent for all nations. Figure 2.1 below presents the trend in smoking prevalence among all persons aged 18 and over in the UK between 2011 and 2019; a drop in prevalence from 20.2% in 2011 to 14.1% in 2019 is evident across the UK[1].

Figure 2.1 Prevalence of smoking among adults in the UK between 2011 and 2019[1]



Although smoking prevalence is predicted to continue declining in the future, it is likely that the already present socioeconomic differences in both smoking prevalence and cessation will increase[37]. The literature revealed that smoking prevalence was higher among disadvantaged groups compared to the most affluent groups in England[38-40]. Furthermore, smoking was more prevalent amongst individuals who are unemployed or working in routine/manual occupations and individuals with lower educational qualifications[39]. Similar inequalities are present with regards to smoking cessation. According to Hiscock et al. (2015), smokers from lower socioeconomic backgrounds were less likely to successfully quit smoking compared to smokers from higher socioeconomic backgrounds, even after participation in smoking cessation interventions[40]. Despite the expected continued decline in smoking prevalence, smoking is a leading cause for preventable death and a growing issue for the widening of health inequalities.

2.2.2 Health Consequences

Smoking is known to be detrimental for one's health, reducing both quality of life and life expectancy. In the UK, smoking has been attributed to almost 78,000 deaths annually[1]. Although nicotine, an addictive substance found in tobacco products, has negative health effects such as increasing heart rate and blood pressure, the majority of harm from smoking is due to inhalation and exposure to tobacco smoke[41]. Despite this, some studies have shown that even light smoking or not inhaling smoke can be harmful[42]. Aside from cancer, the adverse effects of smoking on cardiovascular and respiratory health are well-established.

Cancer

One of the major negative health effects of smoking is cancer, specifically lung cancer, which is the third most common cancer in the UK and the leading cause of cancer mortality[43]. According to a systematic review comprising of pooled data involving seven million individuals, the risk of developing lung cancer among current smokers compared to non-smokers was 6.99 greater in women and 7.33 greater in men[44]. Smoking is also responsible for cancers of other parts of the body. For example, 10,300 people in the UK are diagnosed with pancreatic cancer every year, with almost 30% of cases attributed to smoking[45]. Since almost 20% of all new cancer cases and 27% of all cancer deaths in the UK are associated with

exposure to tobacco smoke, smoking is considered a major risk factor for several other cancers such as of the stomach, pancreas, throat, liver, oesophagus and prostate[43].

Cardiovascular Health

Aside from cancer, smoking is also a known contributing factor for the development of many cardiovascular diseases such as coronary heart disease, stroke, congestive heart failure, stable angina, peripheral vascular disease and aortic aneurysms[45]. These diseases are often caused by the initiation and progression of atherosclerosis, also known as the thickening or hardening of arteries[45]. Some mechanisms activated by smoking which predispose individuals to atherosclerosis include vascular inflammation, thrombosis, oxidative stress and dyslipidaemia[47]. A meta-analysis showed that smoking one cigarette per day was associated with up to 50% excess risk of developing coronary heart disease and smoking five cigarettes per day was associated with up to 65% excess risk[46]. The meta-analysis also reported increased odds of having a stroke among smokers compared to non-smokers[46]. The findings indicate that smoking substantially increases the risk of cardiovascular diseases and has important implications for smokers who believe that a light level of smoking is safe.

Respiratory Diseases

Deterioration of respiratory health is another major health issue resulting from tobacco use. Smoking is one of the main risk factors for chronic obstructive pulmonary disease (COPD) which is a steadily growing pandemic with 251 million global cases reported in 2016[47]. Research shows that smoking is responsible for 45% of all deaths from COPD in the world[48]. After COPD, asthma is the second most prevalent chronic respiratory disease globally and also the second leading cause of chronic respiratory disease-attributable deaths[49]. A systematic review found that smokers have a four times greater risk of having COPD and 1.6 times greater risk of developing asthma compared to non-smokers[50]. On a smaller scale compared to COPD and asthma, research on the current global pandemic suggests that smoking is associated with increased severity of disease and death in patients hospitalised with coronavirus disease (COVID-19). According to Hopkinson et al. (2021), current smokers were more likely to report symptoms for COVID-19 than non-smokers[51]. Collectively, the evidence reviewed clearly highlights the damaging effects of smoking on respiratory health.

Other Health Effects

There are several other negative health effects of smoking; it can adversely impact maternal, foetal, bone, dental and skin health. Smoking can increase the chances of ectopic pregnancy, low infant birth weight, preterm delivery and foetal birth defects[52]. It is also linked to infertility and difficulty in conceiving[48]. Additionally, effects of smoking on dental health have been well-established; this includes increased likelihood of discolouration of teeth, bad breath, damaged taste buds and periodontal diseases[48].

Health Effects of Secondhand Smoke

Apart from the health effects of direct consumption of tobacco, adverse health effects from exposure to secondhand smoke (SHS) is a widespread health hazard. Although almost one million people globally die every year due to SHS, 25% of the global population remains exposed to it[53]. The immediate effects of SHS include nausea, headaches and irritation of the nose, eyes, lungs and throat. Long-term exposure to SHS can cause cancer and many of the diseases discussed previously. According to the World Health Organisation (WHO), the risk of coronary heart disease and lung cancer is increased by up to 30% when exposed to SHS[54]. Children are particularly vulnerable to SHS and exposure can lead to an increased risk of several health issues such as asthma, COPD, sudden infant deaths syndrome, middle ear disease, pneumonia and other respiratory illnesses[53-54].

In summary, there are several negative health effects of smoking and exposure to SHS which have been substantiated by many robust empirical research studies. Since smoking, and broadly tobacco use, is a modifiable risk factor, efforts to reduce smoking initiation rates and increase smoking cessation rates could reduce the risk of smoking-related diseases.

2.2.3 Tobacco Control

A series of medical reports and research studies in the 1950s and 1960s, such as the 1964 Surgeon General Report, confirmed the adverse effects of smoking on health and led to the beginning of the fight against tobacco[52]. With growing evidence on the harmful effects of smoking and exposure to SHS, initiatives to lower the prevalence of tobacco use and minimise passive exposure were gradually developed and adopted by countries with the aim of reducing morbidity and mortality rates. Legislation and policy recommendations grew

increasingly popular to address the situation, with recent decades showing significant progress in tobacco control. Two major developments that occurred as the fight against tobacco became a global endeavour include the introduction of the Framework Convention on Tobacco Control (FCTC), and based of the FCTC, the MPOWER tobacco control strategy developed by the WHO[55].

Framework Convention on Tobacco Control

In 2003, the WHO introduced the FCTC, an international public health treaty that contains legally binding obligations for the members and parties involved[55]. The main goal of the WHO FCTC is to set policies across all levels and guide actions of its members to reduce the demand for tobacco and the supply of tobacco products. The FCTC consists of supply reduction strategies such as providing economically viable alternatives for tobacco workers and sellers, restrictions on sales to minors and the elimination of illicit trade in tobacco products[55]. It also contains demand reduction strategies such as price and tax measures, regulation on tobacco products, advertising and labelling, and increasing education and public awareness[55]. Article 14 is one of the demand reduction strategies concerning tobacco dependence and cessation; it specifies the importance of designing and implementing "effective programmes aimed at promoting the cessation of tobacco use" in a variety of environments (e.g. educational institutions, workplaces and healthcare facilities)[55].

MPOWER

Whilst the FCTC provided important guidance for tobacco control, there was a recognisable implementation gap. In order to address this and ensure better monitoring of the application of the FCTC articles, the WHO developed the MPOWER framework[56]. The MPOWER framework (table 2.1) provides more practical guidance to help countries implement effective and appropriate tobacco control strategies[56]. It advises countries to: 1) *monitor* tobacco use and prevention policies by gathering and analysing the data necessary to design, implement and evaluate policies and interventions, 2) *protect* people from tobacco smoke by implementing measures such as smoke-free laws, 3) *offer* people help to quit tobacco use via cessation interventions, education and counselling, 4) *warn* individuals about the dangers of tobacco with labels on tobacco packaging or media campaigns informing individuals about

the harmful effects of tobacco use, 5) *enforce* bans on the promotion and advertisement of tobacco and 6) *raise* taxes to reduce consumption[56].

Table 2.1 MPOWER framework[56]

M	Monitor tobacco use and prevention policies
P	Protect people from tobacco smoke
O	Offer help to quit tobacco use
W	Warn about the dangers of tobacco
E	Enforce bans on tobacco advertising, promotion and sponsorship
R	Raise taxes on tobacco

The MPOWER framework has contributed to successful strides towards battling the tobacco epidemic at a global level. Levy et al. (2018) estimated that between 2007 and 2014, 88 countries in the world adopted a least one MPOWER policy which resulted in the aversion of approximately 22 million deaths attributed to smoking[57]. A report launched by the WHO states that approximately five billion people in the world are protected by at least one of the MPOWER policies, which is a significant increase compared to 2007 when 2.4 billion people were protected by at least one policy[56]. Although, the MPOWER initiative focuses on both the prevention and treatment of tobacco use, according to a WHO report on the global tobacco epidemic, tobacco cessation policies remain the least implemented globally[56]. Therefore, an unmet need of strengthening the implementation of cessation services and support is identified. Consequently, this research thesis targets "O" of the MPOWER initiative (i.e. offering help to quit tobacco use); more specifically, the primary focus of my research is smoking cessation.

Tobacco Control in the UK

The UK has taken large and necessary steps to battle the tobacco epidemic. It signed the FCTC treaty in 2004 and has since built and enforced several legislative measures such as restrictive advertising, establishment of smoke-free areas, standardised packaging including prominent and visual health warnings and prohibition of smoking inside cars with children[58]. According to the latest tobacco control scale report by the Association of European Cancer Leagues (2020), the UK is ranked as the number one in Europe for a fifth time in a row for its tobacco

control activity and comprehensive policies, including the provision of smoking cessation services[59].

2.2.4 Smoking Cessation

Smoking cessation refers to the process of quitting or remaining abstinent from smoking. Aside from long-term health benefits such as lower risk of cancer and cardiovascular diseases, quitting smoking can also have immediate health benefits. For example, even within a day of quitting, blood pressure, heart rate and carbon monoxide levels can be normalised[56]. Despite the known health benefits, quitting smoking is challenging. According to the Global Adult Tobacco Survey, in 2015 60% of smokers wanted and intended to quit smoking, of which 40% made quit attempts in the following year[56]. Since provision of smoking cessation support remains a global challenge, only 4% of quit attempts were successful[56]. Similarly, research shows that in England, even though 60% of smokers want to quit smoking, only 10% make a quit attempt within the following 3 months and without assistance, only 3-4% of smokers successfully quit for a year[60]. On the other hand, with the support of stop smoking advisors and cessation aids, 16% of smokers remain non-smokers after a year of quitting[60]. The large discrepancy between the proportion of smokers who want to quit smoking and the proportion that successfully quit could be explained by the addictive effect of nicotine inhaled through tobacco smoke.

To work towards a tobacco-free generation, the National Health Service (NHS) in the UK offers advice and support to smokers seeking to quit through local stop smoking services (SSS). The aim of these services is to offer high-quality and evidence-based treatment options at a local level. Moreover, the National Institute of Care and Excellence (NICE) in the UK provides guidelines for smoking cessation interventions and services delivered to smokers in primary care and community settings. These guidelines include recommendations for evidence-based smoking cessation interventions including self-help materials, advice on e-cigarettes, education and training for health professionals, information on how to engage with smokers and other methods to facilitate an increase in smoking cessation rates[61]. The main evidence-based services and treatment options recommended by the NICE institute and offered by SSS include nicotine replacement therapy (NRT), medications, behavioural support, self-help materials and other interventions[61].

Nicotine Replacement Therapy

NRT refers to the controlled administration of licensed products that release nicotine into the body which would have otherwise been delivered via cigarettes. However, unlike cigarettes, NRT does not release harmful substances such as tar, cyanide and carbon monoxide[61]. The most commonly used NRT products include inhalation cartridges, nasal spray, gum, transdermal patches and sublingual tablets[61]. According to a systematic review, the use of commercially available forms of NRT as a type of cessation method increase quitting rates by 50-60%[62]. The benefit of using NRT to quit smoking is well-established and clinically recommended by NICE as the first line of treatment for individuals seeking pharmacological help.

Medications

Another type of smoking cessation treatment offered in the UK with the aid of local SSS is medications. One of the medications recommended by NICE for smokers seeking to quit is varenicline as it blocks the reinforcing effects produced by smoking[61]. NICE recommends that smokers seeking to quit start taking varenicline a couple of weeks before their desired quit date and that the medication is prescribed by SSS as part of a behavioural support programme[61]. A systematic review revealed that the likelihood of abstinence for 6 months or longer among smokers that had been prescribed varenicline compared to a control group was 2.24 times greater[63]. Studies also show higher efficacy rates of varenicline compared to NRT and other medications such as bupropion[64].

Another common medication recommended to smokers seeking to quit is bupropion. It was initially developed as an antidepressant but was later licensed to help smokers quit. Bupropion "exerts its effect primarily through the inhibition of dopamine reuptake into neuronal synaptic vesicles. It is also a weak noradrenalin reuptake inhibitor and has no effect on the serotonin system"[65]. It has been proven to have high efficacy in many smoking cessation trials. Bupropion has been found to have similar efficacy rates to NRT and is therefore also clinically recommended as a first line of treatment for individuals seeking pharmacological assistance[64]. Medications such as varenicline or bupropion are recommended as first line of treatment by NICE but in conjunction with behavioural support

programmes. Such combinatorial treatment has been found to lead to the greatest likelihood of successful cessation[66].

Behavioural Interventions

NICE recommends that behavioural support should be available to smokers seeking to quit smoking. There are two forms of available support: individual behavioural support and group behavioural support. Individual behavioural support includes "face-to-face meetings between someone who smokes, and a counsellor trained in smoking cessation"[61]. Sessions generally take place on a weekly basis for at least a month after a quit date is set. A systematic review that included 49 studies and a total of 19,000 participants found that participants who received individual counselling were 57% more likely to have quit in the long-term than individuals who did not receive counselling[67]. Group behavioural support involves the same type of counselling but sessions would take place between a counsellor and a group of smokers at the same time. The counsellor provides information, advice and encouragement to smokers. As highlighted earlier, NICE recommends that individual or group behavioural support is combined with pharmacotherapy[61].

Other Types of Cessation Methods

Aside from behavioural and pharmacological support, there are other types of smoking cessation methods available in the UK, particularly for individuals wanting to quit without professional assistance. This includes self-help materials which can be in the form of manuals or structured programmes to help individuals quit smoking independently without help from health professionals[68]. Self-help materials can be in written (e.g. information leaflets) or electronic (e.g. websites and mobile apps) format.

Another type of smoking cessation method that is increasingly used in the UK but for which evidence is still developing is e-cigarettes. E-cigarettes are handheld electronic vaping devices that heat e-liquids to produce aerosols. Although they are not licensed products in the UK, a systematic review has found with moderate confidence that nicotine e-cigarettes increased the odds of quitting for at least 6 months compared to behavioural support and NRT[69]. However, the evidence is limited to a small number of randomised controlled trials (RCTs) and the long-term health impact is not yet fully understood[69]. Another systematic review of

observational studies suggested that the use of e-cigarettes was not associated with increased cessation among adults[70]. Further research is required to understand the effects of e-cigarettes, as consumer products or prescribed therapy, on smoking cessation more confidently.

There are some methods of smoking cessation which are not provided by SSS such as acupuncture, laser therapy and hypnotherapy. Barnes et al. (2019) reviewed several studies examining the use of hypnotherapy for smoking cessation and found there was insufficient evidence to determine its effectiveness compared to no treatment or other interventions[71]. Similarly, another review found that there is no consistent or bias-free "evidence that acupuncture, acupressure or laser therapy have a sustained benefit on smoking cessation for 6 months or more"[72].

Use of Smoking Cessation Methods via Stop Smoking Services

Studies have demonstrated the effectiveness of local SSS in helping smokers quit and thereby generating a large number of ex-smokers[73]. According to Dobbie et al. (2015), between 2012 and 2013, more than 36,000 premature deaths were prevented due to SSS in the UK[74]. Similarly, Bauld et al. (2016) investigated 1-year outcomes of smokers that received behavioural and cessation medication via SSS in England[4]. The study revealed that engagement and use of smoking cessation services was associated with better quit rates[4]. Additionally, a study found that "approximately 15% of the percentage point reduction in smoking prevalence during 2001 – 2016 in England may be attributable to NHS" local SSS[75].

Despite the promising evidence on the impact of such services, the number of smokers using these services has fallen over the past years[5-6]. The reduction in access to smoking cessation services has been linked to budget cuts among various other reasons[6,73]. Apart from a decline in access, research also shows that the number of individuals making quit attempts fell between 2008 and 2017[5]. Of those individuals that are making quit attempts, the majority are trying to do so without any assistance, which is further substantiated by the significant decline in the number of dispensed prescriptions of NRT and medications for smoking cessation between 2009 and 2020[5]. According to Hughes et al. (2003), only 3-5% of self-quitters are able to achieve abstinence for longer than 6 months[3]. Due to the negative health impact of

smoking, it is important for research to investigate factors that could maximise the likelihood a successful quit attempt.

2.2.5 Success Factors for Smoking Cessation

Despite the well-known adverse effects of smoking and the availability of smoking cessation services, successful quitting rates remain low. Research shows that there are many factors which can impact the success and failure of quit attempts. Several studies have been conducted to better understand these factors. Upon review of the extensive body of literature, factors associated with smoking cessation can be clustered into the following categories: 1) physiological, 2) psychological, 3) social and environmental, 4) behavioural, and 5) cognitive.

Physiological Factors

Physiological factors such as nicotine dependence and degree of withdrawal symptoms are known to be associated with the outcome of smoking cessation. Studies have shown that the level of dependence on nicotine is consistently predictive of successful smoking cessation[76-77]. A systematic review examining the predictors of successful smoking cessation in adult general population samples found that having higher nicotine dependence was associated with lower success in smoking cessation[13]. Similarly, a prospective cohort study examining predictors of smoking cessation behaviours found that across four countries (UK, Australia, Canada and United States), individuals with lower levels of nicotine dependence were more likely to quit smoking[76].

Moreover, many smokers develop symptoms of nicotine withdrawal when they attempt to quit smoking. Some of the major symptoms that smokers experience include increased appetite, poor concentration, restlessness, disturbed sleep, lower heart rate, higher levels of adrenaline and cortisol, and mood changes including irritability, aggression, depression and anxiety[78]. Moreover, since withdrawal symptoms are one of the main motives for smokers to continue smoking, the severity of such symptoms is an important predictor for successful cessation[77-78]. Zhou et al. (2009) conducted a multinational cohort study and found that subjects who experienced severe withdrawal symptoms were more likely to fail at their quit attempt and relapse than those individuals who did not experience withdrawal symptoms[77].

Collectively, the studies reviewed outline the essential role of physiological factors in influencing the success or failure of quit attempts.

Psychological Factors

Aside from physiological factors, psychological factors such as stress levels, depression, anxiety and other psychiatric conditions can also influence successful abstinence. Studies have shown that individuals suffering from depression are less likely to quit smoking than those not suffering from depression[77,79]. A meta-analysis of 42 trials estimated that smokers with depression had 17% lower odds of staying quit in the short-term and 19% lower odds of achieving long-term abstinence[79]. Another study found that "subjects with anxiety/depression before quitting are approximately 30% more likely to relapse" than those without anxiety or depression[77]. Aside from depression, anxiety and stress are also known to be important determinants of successful cessation and abstinence. According to Brown et al. (2001), smokers with higher anxiety sensitivity (i.e. the fear of behaviours or sensations that are a result of experiencing anxiety) and/or recurrent depression history had a higher likelihood of relapsing within a week of quitting[80]. Similarly, Kim & Cho (2014) found that individuals that had a lower perception of stress were 1.26 more times likely to self-report successfully quitting compared to individuals with higher perception of stress in their daily life[81]. Together these studies provide important insights regarding the impact of psychological factors on smoking cessation.

Social and Environmental Factors

Social and environmental factors can also play a role in influencing cessation outcomes. Socioeconomic circumstances, particularly education level, have been found to be strong predictors of smoking behaviours and cessation outcomes. Yang et al. (2015) reported that the odds of successfully quitting smoking increased by 56% for individuals with higher education levels compared lower educational attainment and by 24% for individuals with non-manual occupations compared to individuals with manual occupations[82]. Similarly, another study showed that individuals with a college education were 83% more likely to successfully quit than individuals without a college education[83]. Likewise, environmental factors have also been linked to quitting success. For example, living or working with other smokers, having friends around that smoke and the level of tobacco control policies implemented in an

individual's vicinity can influence cessation outcomes. Lee & Kahende (2007) conducted a study to examine predictors of successful quitting in the United States (US) and found that having a no-smoking policy at work doubled the odds of successfully quitting smoking[83]. Lee & Kahende (2007) also reported that individuals with smoke-free homes were 10 times more likely to successfully quit compared to individuals who lived in homes where smoking took place[83].

Behavioural Factors

Moreover, behavioural factors such as the number of cigarettes smoked, history of past attempts, patterns of smoking behaviour and prevalence of slip-ups are also associated with the outcome of quit attempts[84]. A prominent cohort study investigating the predictors of smoking cessation among adult smokers over a duration of five years showed that a smaller number of cigarettes smoked on a daily basis and a longer time until a smoker smokes the first cigarette in the morning strongly predicted successful smoking cessation[85]. Similarly, the findings of the study also concluded that having a history of quit attempts was associated with increased odds of quitting and remaining abstinent.

Cognitive Factors

The above subsections have reviewed several factors associated with cessation outcomes. Many of the factors discussed are difficult for individuals to amend or change. For example, environmental factors such as smoking policies at the workplace or high availability of tobacco products, and physiological factors such as severity of withdrawal symptoms and nicotine dependence can be difficult to alter at an individual level. However, some cognitive factors that are associated with successful cessation can be influenced. According to Greehalgh et al. (2016), examples of cognitive factors that can predict smoking cessation include self-efficacy, motivation, empowerment, perceived barriers and smoking beliefs[85]. Despite the wide range of factors, my thesis will focus on cognitive factors, specifically self-efficacy and motivation to quit, as they are modifiable at an individual level and rigorously associated with successful cessation according to existing literature.

2.3 Self-Efficacy and Motivation to Quit

2.3.1 Self-Efficacy

Self-efficacy is a concept that has been frequently used in the field of psychology to understand and predict behaviours. Specifically, it is often applied to design and guide health behaviour change interventions for physical activity, weight loss and diet, and alcohol and drug use[86-87]. Similarly, the substantial role of self-efficacy in smoking cessation has been extensively studied.

Defining Self-Efficacy

The concept of self-efficacy was originally proposed by Albert Bandura, who defined it as an individual's "judgment of their capabilities to organise and execute causes of action required to attain designated types of performances"[7]. In other words, self-efficacy refers to an individual's perception about their ability and possession of skills needed to perform a certain behaviour. It can determine whether an individual will initiate coping behaviour and how long continued efforts to tackle obstacles will be sustained[87]. Within the context of smoking cessation, smoking-related self-efficacy refers to an individual's confidence in their ability to quit smoking. More specifically, in this research thesis, self-efficacy in the context of smoking cessation is defined as one's "ability to refrain from smoking when facing internal stimuli and external stimuli"[88].

Measuring Self-Efficacy

Self-efficacy in smoking cessation studies has been measured or operationalised diversely. Some studies use unidimensional methods to measure self-efficacy via single-item questions. For example, in a study by Loprinzi et al. (2015), participants were asked how confident they feel from a scale of 0 to 10 that they could quit smoking now if they decided to[89]. Other studies have also adopted similar single-item measures to operationalise self-efficacy related to quitting smoking[90]. On the other hand, many smoking cessation studies use multi-item scales that measure self-efficacy as a situation-specific construct. Some of the common tools to measure self-efficacy have been summarised in table 2.2. It can be seen that many of the scales include multiple items assessing ability to refrain from smoking in different situations.

Table 2.2 Scales to measure self-efficacy in the context of smoking cessation

Name of Scale	Developers	Description
Smoking Self-Efficacy Questionnaire (SEQ-12)	Etter et al., 2000[88]	• Two dimensions • 12-item scale • Measures confidence in refraining from smoking • Intrinsic and extrinsic self-efficacy
Smoking Abstinence Self-Efficacy Questionnaire (SASEQ)	Spek et al., 2013[91]	• 6-item scale • Measures confidence in not smoking when faced with different situations
Smoking Self-Efficacy Questionnaire (SSEQ)	Colletti & Supnick, 1985[92]	• 17-item questionnaire • Asks participants their confidence to resist urges during 17 different situations

In this thesis, self-efficacy is measured using the Smoking Self-Efficacy Questionnaire, also known as SEQ-12. It is a 12-item tool developed by Etter et al. (2000) that measures the confidence in refraining from smoking when faced with different types of stimuli[88]. It also measures a smoker's ability to refrain from smoking in risky situations that could stimulate cravings and lead to relapses[93]. SEQ-12 was used to assess self-efficacy as it is a common method adopted by other smoking cessation studies[94]. It has also been reported to have high construct, content and predictive validity, high test-retest reliability and high internal consistency[95-96].

Self-Efficacy and Smoking Cessation

The association between self-efficacy and smoking cessation has been well-established in the literature. For example, Smit et al. (2014) found that self-efficacy was an important predictor for a successful quit attempt, with an 18% increased likelihood of staying quit after 6 weeks among smokers with high compared to low baseline self-efficacy[97]. Similarly, Hayrumyan et al. (2018) found that an increase in self-efficacy among smokers seeking to quit was associated with a 1.3 times greater likelihood of quitting[11]. Several other studies have reported similar evidence on the impact of self-efficacy on smoking cessation outcomes[8-11].

Additionally, there is evidence that high self-efficacy is associated with a lower likelihood of relapsing during a quit attempt. For example, Herd et al. (2009) conducted a longitudinal study amongst 1296 ex-smokers from Australia, Canada, UK and the US, which showed that having low self-efficacy significantly predicted relapse even when controlling for duration of abstinence and frequency of cravings[98]. Using a large sample and high external validity due to cross-country data, the study shows that a high level of self-efficacy is vital for maintaining abstinence and provides strong evidence for the importance of self-efficacy for successful quitting[98]. Likewise, Schnoll et al. (2011) found that "participants who exhibited a greater increase in self-efficacy to quit smoking over the course of the first 2 weeks of treatment were significantly more likely to be abstinent at the end of the treatment" and this relationship held for 6 months after the set quit date[95]. The study provides some unique results as it shows that initial increases in self-efficacy during cessation are strong predictors of successful quitting, particularly for long-term success.

The evidence reviewed suggests the pertinent role of self-efficacy as a key predictor of successful smoking cessation, particularly since its impact on cessation has been reported consistently across different types of studies and samples with varying demographics, geographical locations and patient groups. This has important implications about the efforts made to help smokers quit. Strategies implemented in smoking cessation interventions should try to boost the self-efficacy of smokers "to overcome barriers they might encounter once they have made a quit attempt" and therefore improve quitting rates[97]. Self-efficacy is considered a central component to the quitting process and implementing strategies that can help boost the self-efficacy of smokers seeking to quit could significantly help in treating tobacco use and nicotine dependence[87].

2.3.2 Motivation to Quit

Apart from self-efficacy, another important cognitive factor that has been associated with successful smoking cessation is motivation, also known as motivation to quit in smoking-related studies. The following subsections explore how motivation in general and in smoking related-studies is defined, how it is measured in existing studies and in this thesis, and how it relates to smoking cessation.

Defining Motivation to Quit

Motivation in the field of health behaviour change has been conceptualised in a wide variety of ways and applied to several theories of behaviour change, such as the self-determination theory and the transtheoretical theory of change[99]. Some behaviour change theorists state that motivation "includes beliefs about what one should do, and both design and intention to act in a particular way"[100]. Others define motivation as energy and direction which directs and maintains behaviour[99]. Within the context of smoking and smoking cessation, motivation to quit is defined as an individual's readiness to stop smoking[12]. In this research thesis, motivation to quit refers specifically to the level of importance and determination a smoker places on successfully quitting at a given attempt[102].

Measuring Motivation to Quit

Similar to self-efficacy, there are both single-item and multi-item measures of operationalising motivation to quit. Many studies in the literature have used single-item measures to quantify motivation to quit. For example, Kotz and West (2013) developed the motivation to stop smoking scale (MTSS) as part of a large-scale research programme on smoking in the UK[100]. It asks participant to select one statement (e.g. "I don't want to stop smoking", "I want to stop smoking and hope to soon", etc.) that reflects their level of motivation. Several variations of such single-item measures to assess motivation to quit have been adopted in the literature. On the other hand, multi-item scales and tools that measure motivation to quit smoking have also been utilised in existing research. For example, the Mondor motivational questionnaire consists of 15 statements reflecting different motivation to quit levels[101]. For the research presented in this thesis, motivation to quit is operationalised using a 2-item measure adopted and recommended by the National Centre for Smoking Cessation and Training (NCSCT) in the UK[102]. The NCSCT supports the NHS and local authorities in the UK in delivering smoking cessation interventions and evidence-based tobacco control programmes, including the training of smoking practitioners and health professionals. The 2-item measure has also been used often by other smoking-related studies in the literature[103-104]. It asks participants how important it is for them to give up smoking during the current quit attempt and how determined they are to give up, for which participants are asked to select one response.

Motivation to Quit and Smoking Cessation

Similar to the findings on the impact of self-efficacy on smoking cessation, several smoking cessation studies have reported positive effects of motivation to quit. For example, a longitudinal study examining factors which contribute to long-term quit rates showed that smokers with higher baseline motivation to stop smoking were more likely to quit and remain quit compared to smokers with low motivation[17]. Similarly, a RCT with more than 800 participants by Jardin & Carpenter (2012) suggested that "motivation was linked with making a quit attempt, regardless of how quit attempts were defined, as well as achieving 7-day abstinence"[14]. Moreover, other studies have also highlighted the important role of motivation to quit in the cessation process. Ferguson et al. (2005) evaluated the impact of English smoking treatment services on 1-year outcomes[16]. They reported that motivation to quit statistically significantly predicted long-term cessation validated by carbon dioxide readings. Similarly, a study involving 286 Spanish smokers found that participants that had higher pre and post-treatment motivation had 1.36 times greater odds of staying quit after treatment and 4.88 times greater odds of staying quit at 6 months follow-up[15]. Unlike some of the other studies mentioned, Piñeiro (2016) also provided evidence for long-term abstinence from smoking[15].

Evidently, several studies in the literature provide empirical support for the importance and impact of high motivation for successful smoking cessation. It is clear that enhancing motivation to quit is vital for "the overall treatment for tobacco addiction as it increases smokers' enthusiasm, sense of purpose and will to quit"[105]. Therefore, researching strategies that can improve motivation to quit levels of smokers could be of great importance in improving smoking cessation rates and consequently for overall health outcomes.

2.3.3 Methods to Influence Self-Efficacy and Motivation to Quit

Several methods or approaches are used in health behaviour change interventions to influence self-efficacy or motivation to quit. For example, motivational interviewing is often used to help smokers explore reasons for quitting and "make them feel more willing and able to stop smoking"[106]. Similarly, goal setting, providing immediate feedback and enhancing enjoyment or flow are all examples of methods that could foster motivation levels[107].

On the other hand, performance attainment, vicarious experience and social persuasion are methods that can influence self-efficacy. Performance attainment or mastery refers to the successful completion of a task or behaviour[7,87]. For a smoker seeking to quit, this could mean staying abstinent for a day and recognising this as a success. Similarly, vicarious experience involves "exposing the individual to successful behaviour performances or gaining experience through practice"[87]. In the context of smoking cessation, this could mean showing smokers examples of other smokers that have successfully quit smoking after participation in smoking cessation interventions. Alternatively, social persuasion is a method whereby individuals are informed of their capabilities in mastering a behaviour or achieving a goal; in other words, by encouraging and persuading individuals to believe that they can be successful (e.g. via positive reinforcement) , self-efficacy can be enhanced[107].

Research needs to explore strategies that can effectively influence self-efficacy and motivation to quit in order to improve quit outcomes. One such strategy is gamification as it can incorporate some of the above-mentioned methods to influence self-efficacy and motivation to quit. It is also a strategy that can easily be integrated into digital or remote interventions which could improve access, knowledge and behaviour across different population groups, and possibly alleviate health inequalities. However, gamification in smoking-related studies has not been rigorously studied by researchers. Therefore, my thesis focuses on the use of gamification as a strategy to influence self-efficacy and motivation to quit in the context of smoking cessation.

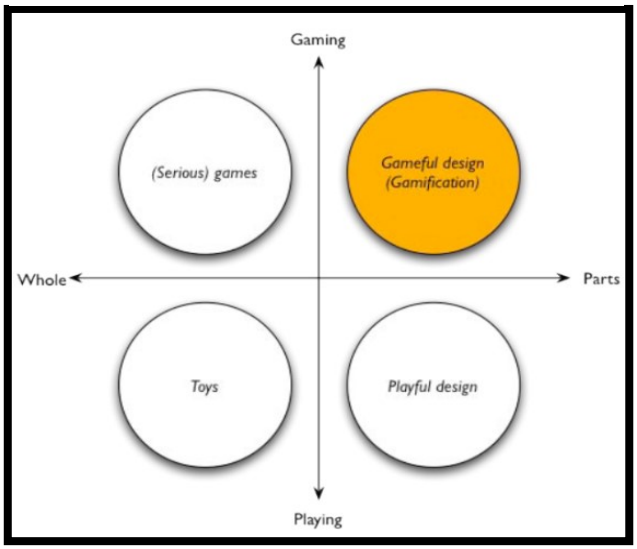
2.4. Gamification

2.4.1 Defining and Conceptualising Gamification

The term gamification was initially used in the context of digital media and marketing, specifically for the development of marketing activities such as point systems, reward cards and loyalty programmes. However, gamification is now increasingly used in education, business, healthcare and various other industries. The rise in popularity of gamification is thought "to be brought about by a number of converging factors, including cheaper technology, personal data tracking, eminent successes, and the prevalence of the game medium"[18].

There are many different definitions of gamification proposed in the literature. Deterding et al. (2011) defines gamification as "the use of game design elements in non-game contexts"[18]. Deterding et al. (2011) builds on this definition by distinguishing between gaming and playing (y-axis), and whole and part games (x-axis) as seen in figure 2.2. Playing is conceived as broad, general, loose and free-form behaviour whilst gaming is structured playing which often involves rules and goals[18]. On the other hand, whole games refer to fully-fledged games and parts refers merely to game elements. Based on this, the top-left quadrant of figure 2.2 includes serious games which are fully-fledged games governed by rules and restrictions to meet a certain goal. Often times the main goal of a serious game is outside of the game itself; for example, using flight simulator games to train pilots or medical simulator games to train doctors. On the bottom-left quadrant is toys; toys give the user the whole experience of a game rather than just parts of it, but with no rules or specific missions that require making meaningful choices. A good example of something that falls under the toys category (whole and playing) is Lego.

Figure 2.2 Conceptualisation of gamification



On the bottom-right is playful design which contains only parts of the gaming experience (i.e. game elements). But similar to toys, there are no specific rules or restrictions which govern the experience. An example cited by van den Boer (2013) for playful design is the *Piano Stairs* which was developed by Volkswagen as part of a marketing campaign[109]. To encourage people to take the stairs rather than escalators, Volkswagen made a flight of stairs look and sound like a piano. Each time someone stepped on a stair, it resulted in the sound of a note from a piano. Since there is an incorporation of game parts/elements but no clear goal or structure, *Piano Stairs* falls under the category playful design. Finally, the top-right quadrant is where gamification is placed. Although gamification involves only parts of the game experience (i.e. game elements), it consists of a structured goal for the user which classifies it as gaming rather than playing. In the context of health behaviour change, gamification is the

most applicable compared to other concepts in the quadrants; this is because the main goal is to change health behaviour which implies that there is structure and a goal (i.e. gaming rather than playing) and at the same time only parts of a game experience are incorporated into behaviour change interventions rather than full-fledged gaming (i.e. parts rather than whole).

Another definition of gamification, offered by Kapp (2012), takes upon a much broader view by defining gamification as "the delivery of content—for a purpose other than pure entertainment—using game-based thinking and mechanics"[110]. In contrast to Deterding et al. (2011), Kapp (2012) states that a rule or structured system governing the experience is not required for gamification[110]. The only factor which defines gamification is that the purpose of it must be other than entertainment; this implies there is no difference between playful design and gamification. For example, a game which is used for educational purposes would be regarded as gamification and not a serious game because the primary purpose is education and not pure entertainment. Therefore, the *Piano Stairs* example discussed earlier which is categorised as playful design according to Deterding et al. (2011) would be considered as gamification according to Kapp's definition.

Moreover, in contrast to the previous two definitions of gamification, Huotari & Hamari (2012) describe gamification as "a process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation"[111]. In other words, whilst the definition acknowledges that gamification is a process, it focuses rather on the goal of gamification instead of its methods. In doing so, this definition challenges the notion that gamification only occurs when game elements are used in non-game contexts and environments. Furthermore, Zichermann and Cunningham (2011) also define gamification as "the process of game-thinking and game mechanics to engage users and solve problems"[112]. Similar to Huotari and Hamari (2012), this definition focuses on the goal of gamification, particularly user engagement and problem solving, rather than on the method or process of gamification. Zichermann and Cunningham (2011) analyse various examples of gamification to demonstrate the consistency and appropriateness of their definition. One such example includes *Nike+* which "engages people in their running activities and solves the problem of not exercising enough"[113]. Another interesting example is the mobile application *Chore Wars*.

The app engages and motivates people to do their chores, but also solves the problem of neglecting and putting off chores. Whilst Zichermann and Cunningham (2011) provide an easily applicable and comprehensible definition of gamification, it does not effectively allow for the distinction between gamification (which includes elements of games) and games (fully-fledged whole games).

As a result of the ongoing digital transformation, some researchers have modified the definition of gamification to be in line with this trend. According to Gartner, a research institution, gamification is "the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals"[114]. This definition specifically addresses the medium through which gamification takes place. Domínguez et al. (2013) further narrows the definition of gamification as "incorporating game elements into a non-gaming software application to increase user experience and engagement"[115]. With the increase in use of smartphone applications, social media and the internet of things, the definition of gamification can be limited and targeted to the digital realm. However, this is very restrictive and does not necessarily shed light on the important defining factors of gamification.

When comparing the different definitions of gamification, it is clear that they all view gamification as a process or an action. Although not all definitions iterate the goal of gamification (e.g. problem solving, engagement, motivation etc.), they do view gamification as a process. The conflict between the definitions lies rather in how they distinguish between gamification and serious games. For the research presented in this thesis, gamification is defined by integrating components of multiple definitions in the literature; the definition used in this thesis acknowledges that gamification is a process with a specific goal and also considers the ongoing digitalisation trend. Consequently, in this research thesis, gamification is defined as:

Gamification is a process whereby game elements (also referred to as features or tactics) are deliberately used in non-game contexts for purposes other than to entertain, such as to motivate or digitally engage users to solve problems and achieve specific goals.

2.4.2 Measuring Gamification

Although multiple definitions of gamification have been proposed, not many methods of measuring or operationalising gamification were found in the literature. Edwards et al. (2016) operationalised gamification by examining whether one of the following techniques was incorporated into the intervention: rewards, avatars, prizes, badges, leaderboards, competitions and challenges[22]. On the other hand, Zichermann and Cunningham (2011) developed a framework where gamification was measured by identification of game elements such as points, levels, leaderboards, badges, challenges and quests, onboarding and engagement loops[112]. Similar to other studies described above, Lister et al. (2014) developed their own method which was developed by establishing common themes found in the existing literature on gamification[116]. They recognised the following gamification elements in their study: leaderboards, levels, digital rewards, real-world prizes, competitions and social pressure[116]. Although many of the described methods to measure gamification are similar, no standard or empirically based approach was identified.

However, one prominent framework often used by existing studies to examine gamification was developed by Cugelman (2010)[21]. Whilst this framework does not provide a quantitative or operational method of measuring level of gamification, it does provide a method to identify the presence of game elements in non-game contexts. Cugelman (2010) identified seven persuasive gamification strategies linked to behaviour change upon reviewing popular gamification taxonomies from academic and non-academic sources[21]. He named these persuasive strategies the broad principles of gamification (table 2.3). Additionally, his framework included a list of on-screen features, also called gamification tactics, that users interact with, and that map on to corresponding broad principles (table 2.3). For example, the gamification strategy of comparing progress with self and others can be realised with the gamification tactic of showing game leaders. An advantage of Cugelman's framework of gamification is that it was developed based on an analytic review of other taxonomies and studies.

Table 2.3 Gamification strategies and tactics[21]

Gamification Strategies	Gamification Tactics
Goal setting: Committing to achieve a goal	Providing clear goals
Capacity to overcome challenges: Growth, learning and development	Offering a challenge
	Using levels (incremental challenges)
Providing feedback on performance: Receiving constant feedback through the experience	Providing feedback
Compare progress: Monitoring progress with self and others	Showing the game leaders
	Show progress
Reinforcement: Gaining rewards, avoiding punishments	Allocating points
	Giving rewards
	Providing badges for achievements
Fun and playfulness: Paying out an alternative reality	Giving a story or theme
Social connectivity: Interacting with other people	-

Another method of assessing gamification was developed by Deterding et al. (2011)[18]. Upon review of existing taxonomies in the literature, Deterding et al. (2011) developed a framework which incorporated game design elements based on varying levels of abstraction and ordered them from concrete to abstract[18]. The level-model makes a distinction between interface design patterns and game design patterns or mechanics because "although they relate to the shared concept of pattern languages, unlike interface design patterns, neither game mechanics nor game design patterns refer to implemented solutions" and hence they are treated as more intangible and abstract[18]. Compared to Cugelman (2010), the level-model is more generalised but also more difficult to apply.

Overall, it is evident that whilst some methods of identifying gamification are found in the literature, they can be abstract and difficult to use. The on-screen gamification tactics (part of Cugelman's framework) is commonly used by existing studies as it can easily be applied to digital technologies and interventions[21]. Consequently, this research thesis will base the operationalisation and identification of gamification and game elements on the framework developed by Cugelman (2010)[21].

2.4.3 Practical Applications and Impact of Gamification

Gamification has been applied to many different industries and subfields such as business and marketing, education and learning, social networking, management, e-services, crowdsourcing and healthcare[117]. It was initially used in the field of business and marketing to increase customer or brand loyalty, stimulate employee motivation and engagement levels, implement persuasive marketing techniques and promote sales[117-118]. Some examples of the use of gamification in business and marketing include programmes to foster brand loyalty (e.g. frequent-flyer programmes), campaigns to promote sales (e.g. My Starbucks Rewards and McDonalds Monopoly) and platforms to improve employee productivity (e.g. Nitro for Salesforce).

Aside from business and marketing, gamification has also been applied to other fields such as education and learning. Many studies have investigated the effects of gamification in the classroom and other education settings. Research has identified that current problems in modern education are "related to the lack of engagement and motivation of students to participate actively in the learning process" as well as adapting teaching methods to be in line with digitalisation trends[119]. As a result of this growing concern in modern education, gamification has been often applied to curriculum design and teaching delivery. Studies have shown that by creating an immersive world for students to learn through the use of gamification, higher knowledge retention, motivation and engagement levels can be achieved[20]. According to Harold (2015), self-efficacy was the most frequently reported advantage of a gamified classroom as gamification methods increased self-efficacy by improving confidence[20].

Another study found that participation in a gamified course on how to use a Windows computer server was associated with a higher level of confidence among students in their ability to use the server adequately compared to students of the non-gamified course[120]. The findings from the study conclude that self-efficacy is "a key ingredient to creating aptitude and gamification is a pedagogy that dramatically increases self-efficacy"[120]. Similarly, a study by Smiderle et al. (2020) reported that students who engaged with a gamified learning system submitted solutions with a significant improvement in quality compared to students who engaged with the non-gamified learning system[121]. It can be seen that there is evidence of

gamification improving the objective output of students in educational settings but also having an effect on cognitive factors such as motivation, self-efficacy and engagement.

Gamification also has important applications in the field of healthcare. Similar to its application to education within the classroom, gamification has been used for the training of medical doctors and pharmacists. Wolf et al. (2017) found that the delivery of a game-based intervention increased the self-perception of knowledge in 19 domains of pharmacy training[122]. Similarly, gamification has been used to improve patient engagement, aid companies in improving the health and productivity of their employees and assist health insurance companies in encouraging their customers to adopt healthier lifestyle habits. Gamification is also frequently applied to health behaviour change interventions. Since risk factors such as high blood pressure, tobacco consumption, elevated blood glucose and insufficient physical activity are leading to high prevalence of chronic diseases, behaviour change interventions have become fundamental levers to reduce the burden of chronic conditions. Evidence from a systematic review suggests that in the context of health behaviour change, gamification can have a positive impact on psychological and behavioural health outcomes[23].

For example, one study examined the impact of a gamified intervention at an elementary school cafeteria on the consumption of fruit and vegetables[28]. The study found that fruit and vegetable consumption was higher on days during which students engaged with *Fit Game*, a game-based intervention promoting healthier dietary choices[28]. Apart from its application to face-to-face behaviour change interventions, gamification has also frequently been applied to remote or digital health behaviour change interventions, particularly mobile apps. For example*, Zombies, Run!* is a gamified mobile app to motivate individuals to engage in physical activity by providing a story of having to outrun zombies to survive an apocalypse. Moran & Coons (2015) revealed that the app increased the motivation of participants to run and uplifted their confidence[123].

Similarly, Thorsteinsen et al. (2014) also suggested that gaming elements in physical activity interventions increased the motivation of individuals to engage in physical activity[19]. Aside from physical activity, gamified mobile apps have been developed to help those battling

depression (e.g. SPARX), self-management of diabetes, increase adherence to medication use (e.g. MangoHealth) and for the prevention and management of various other health conditions. The mobile app *SPARX* to battle depression was found to reduce depression scores and act as a potential alternative to usual treatment in primary care settings for adolescents suffering from depressive symptoms[124]. As a result of the easy implementation of gamification into digital interventions such as mobile apps, and the parallel growth in smartphone usage, the application of gamification in mHealth has received increased interest.

2.5. Mobile Health (mHealth)

2.5.1 Definition and Prevalence

According to the WHO, mHealth is defined as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices"[125]. In other words, it involves the use of mobile and wireless technologies to support the attainment of health objectives. The application of mobile technologies within the health industry has grown immensely over the past years, partly due to the rise in production and use of smartphones and tablets that give individuals easier access to the Internet and digital services. Recent estimates indicate that at the end of 2019, there were approximately 8.3 billion mobile cellular subscriptions in the world and more than half of the global population was using the Internet[126].

Narrowing down to the UK, according to a 2020 report released by Ofcom, the UK's communications regulator, 81% of the population used smartphones, up from 27% in 2011[127]. Other population-based surveys found similar growth trends in ownership and usage of mobile phones, particularly smartphones[128]. The adoption of smartphones remains the highest among adults aged 18 to 24 years and 25 to 34 years[128]. Since 2012, the largest increase in smartphone use has occurred among individuals aged 45 to 54 years and 55 to 75 years old[128]. As a result of the increased use of smartphones and tablets, the development and availability of mobile apps has also risen. One study reported that 100,000 mobile apps were available in the UK in 2017, and since then the number of available apps is likely to have increased[129]. Other studies report that approximately six million mobile apps are available globally on leading app stores such as Google Play and the Apple Store[130]. Mobile apps have

been used to support and improve health outcomes by helping people actively monitor and manage health conditions[131]. Evaluating and understanding the benefits of mHealth, particularly mobile apps, has increasingly become the focus of academic research.

2.5.2 Benefits and Applications of mHealth

There is a wide array of research providing evidence for the benefits of mHealth. Due to their wide reach and low-cost, mHealth solutions are able to provide cost-effective methods of information dissemination and access to health services and promotion interventions[125]. Moreover, mHealth solutions are able to provide persistent and real-time access and portability of health care to those seeking it. Therefore, mHealth provides a channel of communication and support that can help overcome barriers to accessing treatment such as transport, availability and cost.

As a result of such benefits, mobile technologies have often been applied in the field of health care; some applications include remote data monitoring, disease outbreak tracing, communication and training for healthcare professionals, education and awareness, and diagnostic and treatment support including self-management[125]. mHealth has also been used to support a wide range of health outcomes. For example, Schoeepe et al. (2016) reviewed studies that explored the use of smartphone apps in interventions to improve physical activity, sedentary behaviour and dietary habits[132]. The review found "modest evidence that app-based interventions to improve diet, physical activity and sedentary behaviour can be effective"[132]. Similarly, another systematic review including 6170 studies showed that smartphone based physical activity interventions lead to increases in objectively measured physical activity levels compared to control groups[133]. Overall, the meta-analysis in the review supported the effectiveness of mobile apps in improving physical activity levels[133]. Similar positive findings have been reported in a study focusing on mobile apps for weight loss as participants who engaged with mobile app weight loss interventions consumed more servings of vegetables per day than the control group[134].

Although a large proportion of studies have focused on physical activity and diet, there has also been research examining the impact of mHealth for chronic conditions such as diabetes. One systematic review found statistically significant differences in glucose levels among

participants of interventions for diabetes management via mHealth technologies (e.g. mobile apps, telemedicine etc.) compared to control groups[135]. Additionally, studies have also investigated the use of mobile app health behaviour change interventions on mental health outcomes. A meta-review comprising of seven meta-analyses reported that mobile apps "for anxiety and depression hold great promise with clear clinical advantages, either as stand-alone self-management or as adjunctive treatments"[136]. There is evidently a large body of literature supporting the use of mHealth in bettering health outcomes in a variety of subfields including diabetes care, mental health, physical activity and diet. Similarly, there is also some research in the literature investigating the impact of mHealth on smoking cessation.

2.5.3 mHealth and Smoking Cessation

Positive effects of mHealth solutions have also been found in relation to smoking cessation. Firstly, there are a large number of smoking cessation apps currently available. According to one study, there were approximately 400 smoking cessation apps available in the US, UK and Australian market in 2015[137]. Another study identified 546 mobile apps for smoking cessation in the US market alone[138]. With the proliferation of smartphone usage and the booming app markets, this number is likely to have grown.

A Cochrane review examining the impact of mobile phone-based interventions on smoking cessation demonstrated that participants who engaged in mobile phone-based cessation interventions had better 6-month cessation outcomes compared to control groups[24]. The review also concluded that smokers who received support from mobile phone-based interventions were 1.6 times more likely to remain quit compared to those who did not receive such support. The findings from the systematic review are robust and promising for the use of mobile technology for smoking cessation. However, the majority of the studies in the review focused on text-messaging based interventions.

Although not as robust, there have also been a handful of studies examining the impact and use of mobile apps for smoking cessation. These studies can be categorised into single-arm trials that examine the use of one mobile app without comparison to a different intervention and double-arm trials which compare the impact of a smoking cessation mobile app to another app or intervention. Iacoviello et al. (2017) conducted a single-arm trial of an app

called *Clickotine* and reported a rate of 26% for 28-day smoking cessation[139]. On the other hand, Bricker et al. (2017) also conducted a single-arm trial for an app called *SmartQuit 2.0* and reported a rate of 21% for 7-day abstinence and 11% for 30-day smoking cessation after 8 weeks of follow-up[138]. There was less variation in smoking cessation rates among double-arm trials, with 7-day abstinence rates estimated to reach up to 13%[140-141]. A more detailed overview of some of the studies investigating the impact of a smoking cessation mobile app on smoking cessation outcomes can be seen in appendix A (table A1).

In light of the existing body of literature, it is evident that there is promising evidence on the effectiveness and potential of mHealth in the context of smoking cessation. Efforts in developing apps that ensure high engagement, usage and adherence could have substantial benefits for successful smoking cessation. A strategy that could positively impact engagement and influence crucial success factors for smoking cessation is gamification. However, gamification in the context of smoking cessation and mHealth has not been extensively studied in the current literature.

2.6 Smoking Cessation, Gamification and mHealth

To date, a large proportion of research on smoking cessation mobile apps have focused on feasibility and usability or design and development of interventions[25-26,29]. Only a handful of studies have investigated the impact of gamification in smoking cessation mobile apps on health outcomes such as quitting rates, or factors associated with quitting. One qualitative study conducted by El-Hilly et al. (2016) recruited 16 smokers that were split into two groups[30]. One group was exposed to a gamified mobile app (Kwit) and the other group to a non-gamified mobile app (Puff Away)[30]. Aside from gamification, the apps presented similar information to the smokers and participants were interviewed multiple times over the course of a month. The findings of the study indicated that "participants using the gamified intervention demonstrated greater levels of motivation and subsequent engagement than the non-gamified cohort"[30]. Furthermore, the study also provided indications that gamification elements such as achievements and rewards stimulated self-efficacy through feedback and monitoring which was not present in the non-gamified intervention. Whilst the findings of this study are promising, the purely qualitative nature of the research hinders the reliability and replicability of the findings. Moreover, the small sample size of 16 participants

is limited and therefore hampers the external validity of the results. Similarly, Tudor-Sfetea et al. (2018) also conducted a qualitative study to explore participant perception of two gamified smoking cessation mobile apps (Quit Genius and SmokeFree)[31]. Although the apps were gamified, the study focused on the general perception of app features and engagement with the app rather than on the impact of gamification specifically.

Another study by Pløhn & Aalberg (2015) included 255 participants who used a web-based cessation programme named *freeFromNicotine*[27]. The programme was 50 days long, took the form of a pervasive game and was tailored to each respondent's smoking habits. The study concluded that "participants who managed to quit smoking after completing the course mentioned competition as an important motivational factor and that gamification and design principles provide successful and can be deployed in other types of learning games"[27]. However, the study was qualitative and did not deliver the intervention via a mobile phone.

There have been some studies on gamified smoking cessation mobile apps that have adopted quantitative methodologies. For example, Mulcahy et al. (2016) recruited 221 participants and asked them to use one of two apps, *My Quit Buddy* (for the general population) and *Quit for You Quit for Two* (geared towards pregnant women)[142]. The study highlighted that certain gamification elements such as challenges, virtual training, and character incorporation, increased satisfaction with the mobile app. This in turn had an effect on "behavioural intention to quit smoking"[142]. Although this study provides some initial evidence for the positive effects of gamification in the context of smoking cessation and mobile apps, the focus of the study was on experiential value and satisfaction of a consumer, and therefore adopted a service marketing lens rather than a health behaviour change perspective. Moreover, participants were only asked to use the apps for 2 weeks after which no follow-up was conducted. Unlike Mulcahy et al. (2016), one study retrospectively investigated the impact of a gamified smoking cessation mobile app with a focus of health behaviour change. The study found that the gamified mobile app had a positive impact on well-being, empowerment and inspiration[143]. Whilst the study had a large sample size, the effects or influence of specific features was not investigated.

Based on a thorough review of the existing literature, it is evident that the majority of studies focus on the development, design and usability of gamified smoking cessation apps rather than the impact or effects of gamification. The few studies that do examine effects of gamification integrated into mobile apps are qualitative in nature and suffer from small sample sizes. There is a need for research to quantitatively investigate the possible effects gamification in mobile apps can have on cognitive outcomes that are critical for smoking cessation.

2.7 Chapter Summary

This chapter provides a review of the existing literature on the main components of this research thesis: smoking, self-efficacy, motivation to quit, gamification and mHealth. Smoking remains a dominant cause of chronic diseases and premature mortality. Whilst a majority of smokers want to quit, a large proportion of smokers seeking to quit are not able to do so. Some factors associated with successful cessation include self-efficacy and motivation to quit. This chapter defines these factors and presents findings on existing studies to better understand their relationship with smoking cessation. Gamification is a strategy that can influence self-efficacy and motivation to quit levels. This chapter reviews different definitions of gamification and presents a commonly adopted conceptualisation of it. The diverse applications of gamification are reviewed, including its application to health behaviour change interventions – particularly smoking cessation mobile apps. Finally, the chapter discusses the strengths and limitations of existing studies on gamified smoking cessation mobile apps.

Chapter Three: Review of Popular Mobile Apps for Smoking Cessation

3.1 Introduction

Mobile apps have become a popular method of supporting change in health behaviours, such as smoking cessation. Given the promising evidence on the benefits of mHealth[144], and the increasing adoption rates of smartphones, it is important that research systematically examines the content embedded and the strategies integrated into mobile apps for smoking cessation. One strategy that has been found to positively influence engagement with mobile apps, a crucial factor for the success of smartphone-based solutions, is gamification[145-146]. Despite initial evidence for the benefits of gamification for app engagement and health behaviour change[116], there is little knowledge on the application of gamification in smoking cessation mobile apps.

In the literature, two reviews were identified which explored the use of gamification in health apps. Lister et al. (2014) conducted an analysis of fitness and diet apps available on the US Apple store in 2014; the review found widespread use of gamification but low adherence to evidence-based guidelines[116]. On the other hand, Edwards et al. (2016) systematically reviewed mobile apps for health and wellness available on the UK market in 2015 for gamification and found that only 4% of the 1680 identified apps included gamification[22]. Moreover, out of the apps that incorporated gamification, only four targeted smoking cessation. Both mobile app reviews explored the use of gamification in the context of health behaviour change, but neither specifically focused on mobile apps for smoking cessation. In order to address this, and inform the next stages of my research, the review presented in this chapter examined the use of gamification in mobile apps for smoking cessation available in the UK.

Aside from the use of gamification, there is also limited knowledge on the adherence of smoking cessation apps on the UK market to evidence-based guidelines. Although there have been some reviews which investigate whether smoking cessation apps are in line with treatment guidelines, several have focused on apps available in the US and other markets

such as Australia, Portugal and South Korea due to country-specific screening criteria[147-152]. Only two mobile app reviews were identified which examined apps specifically for smoking cessation on the UK market[153-154]. However, both reviews are outdated (i.e. app searches conducted in 2012 and 2014), excluded Android apps and focused on inclusion of behaviour change techniques rather than adherence to treatment guidelines.

Apps that follow evidence-based guidelines or are developed with input from healthcare professionals and researchers are more likely to include reliable content of higher quality, thereby increasing the likelihood of app effectiveness[155]. Moreover, if a smoker uses an "app for assistance in quitting and finds strategies that are not likely to be helpful, it could present a barrier to quitting"[150]. It could lead to a loss of motivation and lack of willingness to pursue other smoking cessation interventions. Due to the negative consequences of using apps that are not empirically based and therefore less likely to be effective, it is important that an up-to-date review of currently available smoking cessation mobile apps is conducted. Aside from examining general app characteristics, I conducted a mobile app review that assessed app adherence to UK-specific treatment guidelines to gain a deeper understanding of the scientific basis of the content presented in apps used by the public. The review also investigated the incorporation of gamification in order to further understand the use of gamification in digital smoking cessation interventions and to inform the next phases of my research.

3.2 Aims and Objectives

Based on the gaps in existing research and the constantly evolving mobile app market, it is essential that a more current review of smoking cessation mobile apps is conducted. Consequently, this mobile app review had three main objectives:

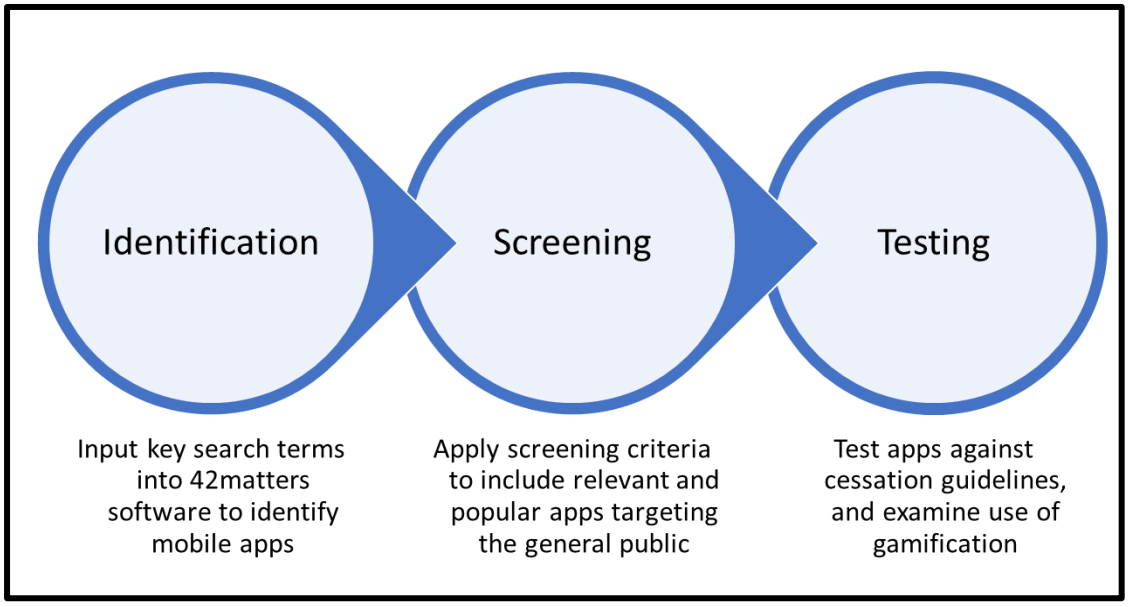
I. Gain insight on the general characteristics (e.g. price and ratings) and main functionalities of mobile apps for smoking cessation available on the UK app market in 2018.
II. Investigate whether smoking cessation apps on the current UK market adhere to the following treatment guidelines: 1) smoking cessation guidelines for self-help materials developed by NICE[156] and 2) Five A's framework for health behaviour change recommended by the WHO[157].

III. Identify the types of gamification elements and the level of gamification incorporated into mobile apps for smoking cessation available on the UK market in 2018.

3.3 Methodology

The mobile app review was conducted in three different stages: identification, screening and testing (figure 3.1). After apps for the review had been identified, they were screened against inclusion and exclusion criteria and then tested for adherence to cessation guidelines and adoption of gamification.

Figure 3.1 Methodological stages of the mobile app review



3.3.1 Identification: Search Strategy

To identify smoking cessation mobile apps available on Android and iPhone Operating System (iOS) platforms in the UK app market, a software called *42matters* was used[158]. It is an online app market explorer which provides information and insight regarding app markets and audience data such as ratings and number of downloads. *42matters* is a tool that has been frequently used in previous reviews of mobile apps for health behaviour change[159-161]. On 19th February 2018, application programming interfaces were extracted from *42matters* after inputting the search terms stop smoking, quit smoking and smoking cessation. The search terms are consistent with past reviews examining apps for smoking cessation[148,150-151,153].

3.3.2 Screening: Inclusion and Exclusion Criteria

After identification of the mobile apps using the software, apps were screened by two reviewers independently. A third reviewer was appointed to resolve any discrepancies or disagreements between the initial reviewers. During the preliminary screening phase, apps were screened using only the data captured by *42matters*. Duplicate apps on both mobile platforms were eliminated based on unique identification numbers assigned to each app by *42matters*. In addition to duplicates, apps that had less than five individual ratings were eliminated. The Apple store displays the rating of an app if it has received five individual ratings, otherwise it presents the app as unrated. In order to treat apps in both platforms equally, the same cut-off point of having a minimum of five individual ratings was also applied to apps from the Google Play Store. Similar to other mobile app reviews, apps with less than 4-star rating were also excluded[162]. Although both app stores do not clearly reveal the methodology adopted to rate and rank apps, using popularity determined by metrics such as user ratings, number of ratings and number of downloads is a common practice in mobile app reviews as it ensures that the most widely used and liked apps are evaluated[162-164].

After the preliminary screening stage, a more thorough screening process was conducted through review of app descriptions and app screenshots provided on the Google Play and Apple store landing pages. Table 3.1 summarises the further inclusion and exclusion criteria used to screen the apps. Apps that did not have the primary aim of helping users quit smoking were excluded. Similarly, apps that were not in English, not related to smoking cessation but still captured by the software, required additional equipment such as DVDs or smartwatches and apps that targeted specific patient groups (e.g. health care professionals) were excluded. Apps that focused primarily on hypnosis were excluded as there is not enough evidence to determine the effectiveness of hypnosis for smoking cessation[71].

After apps were excluded based on the review of landing pages, the remaining apps were downloaded onto an iOS or Android smartphone. The apps were then reviewed again against the inclusion and exclusion criteria summarised in table 3.1. During this final screening stage, apps that had installation errors or software problems upon download were excluded. The apps that remained after this stage of screening were included in the mobile app review and tested for adherence to evidence-based guidelines and incorporation of game elements.

Table 3.1 Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Primary aim of the app is to help smokers quit or reduce smoking. App must clearly state that this is its main purpose	App claims it can be used to help quit smoking but this is not the primary aim of the app
App is available in the UK (i.e. no country restriction upon download)	App is not in the English language
Apps that are fully functional without any major software issues (e.g. crashes upon download or use, videos and features do not load)	App is not available in the UK
App targets the general public	App has less than five user ratings
	App has less than a 4-star rating
	Hypnosis apps
	App is designed for healthcare professionals or specific patient groups
	App targets substances other than nicotine or other forms of smoking (e.g. marijuana)
	App requires compatibility with other devices or products (e.g. smartwatch, DVDs)

3.3.3 Testing: Coding and Classification of Apps

During the testing stage, all the mobile apps that met the screening criteria were reviewed for 30 minutes on the day of installation. Reviewers also examined the apps the next day for approximately five minutes to check for any additional notifications or feedback delivered by the app. Similar to the screening stage, discrepancies between the two reviewers were resolved by a third reviewer. The apps were tested to identify main functionalities, adherence to smoking cessation guidelines and incorporation of gamification.

Main Functionalities

Every app was assessed to identify the primary feature or functionality it adopted to help smokers quit smoking. The categories for functionalities (table 3.2) were initially developed by the National Tobacco Cessation Collaborative, but several mobile app reviews have used the same categories to classify features of smoking cessation apps[148-149]. The main functionalities include the following: tracker, calculator, rationing, informational, game, lung health monitor and other.

Table 3.2 Classification of mobile app functionalities

Type of App	Description
Tracker	The app tracks the number of days elapsed since the user quit and/or the number of days until the user's quit date
Calculator	The app primarily calculates the amount of money a smoker saves by not smoking and/or the health benefits attained by not smoking
Rationing	The app prompts the user to limit the number of cigarettes smoked and/or how often the user can smoke a cigarette (e.g. time limits)
Informational	The app provides information in the form of text and images to provide the user with knowledge on various aspects of smoking cessation
Game	The app takes the form of a game to help users quit
Lung Health Monitor	The app measures and tracks the user's lung function and health simultaneously to the user's smoking habits
Other	Any other approaches/features that have not been described above

Smoking Cessation Guidelines

Apps were also tested for their adherence to two sets of evidence-based smoking cessation guidelines: Five A guidelines recommended by the WHO and smoking cessation guidelines for self-help materials developed by NICE[156]. The Five A guidelines for behaviour change have been used for various behaviours such as smoking, alcohol consumption, dietary patterns and physical activity[157]. They are generally accepted as an effective tool to inform and develop health behaviour change interventions. Applied to smoking cessation, the guidelines include: 1) Ask – about tobacco use, 2) Advise – tobacco users to quit, 3) Assess – readiness to make a quit attempt, 4) Assist – with the quit attempt and 5) Arrange – follow-up care[157].

The NICE guidelines are official evidence-based guidelines for self-help materials in the UK, such as information leaflets, online educational material and mobile apps[156]. The NICE guidelines for self-help materials are tailored for smoking cessation interventions that smokers could use independently, "without the help of health professionals, stop smoking advisors or support groups"[156], such as mobile apps, to aid quitting or reducing the number of cigarettes smoked. The guidelines state that the materials should include information on harm reduction methods (i.e. cutting down before stopping or abstaining), benefits of quitting, planning a schedule (i.e. setting a quit date), strategies to cut down and where to get further support. They should also include information on NRT, including types of NRT, its

benefits, how to use it and where to get access to it. Supplementary table A2 (appendix A) provides further details on the two sets of evidence-based guidelines.

Gamification

Gamification was assessed using an architecture developed by Cugelman (2010) which was reviewed in chapter two of this thesis[21]. The first part of the architecture includes the persuasive and broad principles of gamification, named gamification strategies. The seven gamification strategies assessed in the mobile app review include: goal setting, capacity to overcome challenges, feedback on performance, reinforcement, compare progress, social connectivity, and fun and playfulness. The second part of the architecture includes on-screen features of gamification which users are able to interact with, named gamification tactics. The 10 gamification tactics assessed in the mobile app review include: clear goals, challenges, levels, points, progress, feedback, rewards, achievements/badges, game leaders and story/theme. Further detail on the gamification strategies and tactics is presented in chapter two of this thesis (section 2.4.2). Gamification tactics are often interchangeably referred to as game elements or gamification features in this thesis.

3.3.4 Data Analysis

Descriptive statistics were used to examine general app characteristics, such as price, ratings, number of ratings and types of app functionalities or features incorporated. Similarly, adherence to guidelines (Five A and NICE guidelines) and use of gamification was also explored using descriptive statistics. To examine the level of adherence to the Five A's, apps were categorised into the following groups: none (adherence to no guideline), low (adherence to 1-2 guidelines), medium (adherence to 3-4 guidelines) and high (adherence to all 5 guidelines). To examine the level of adherence to the NICE guidelines, apps were categorised into the following groups: low (adherence to 1-3 guidelines), medium (adherence to 4-6 guidelines) and high (adherence to 7-9 guidelines).

Level of gamification strategies was categorised into the following groups: none (no strategy was incorporated into the app), low (1-2 strategies), medium (3-5 strategies) and high (6-7 strategies). Level of gamification tactics was categorised similarly: none (no tactic was incorporated into the app), low (1-3 tactics), medium (4-7 tactics) and high (8-10 tactics). The

cut-off points used to operationalise gamification levels were arbitrary due to the fact that no previous research identifying specific thresholds with meaningful implications was found.

Lastly, to examine differences in adherence to evidence-based guidelines and gamification use between the two mobile platforms (iOS and Android), Pearson chi-square tests for independence were performed. For frequency counts of less than five, Fisher's exact test of independence was conducted. Statistical significance was determined at the 5% (.05). All statistical analyses presented in this mobile app review were conducted using the software STATA 16.

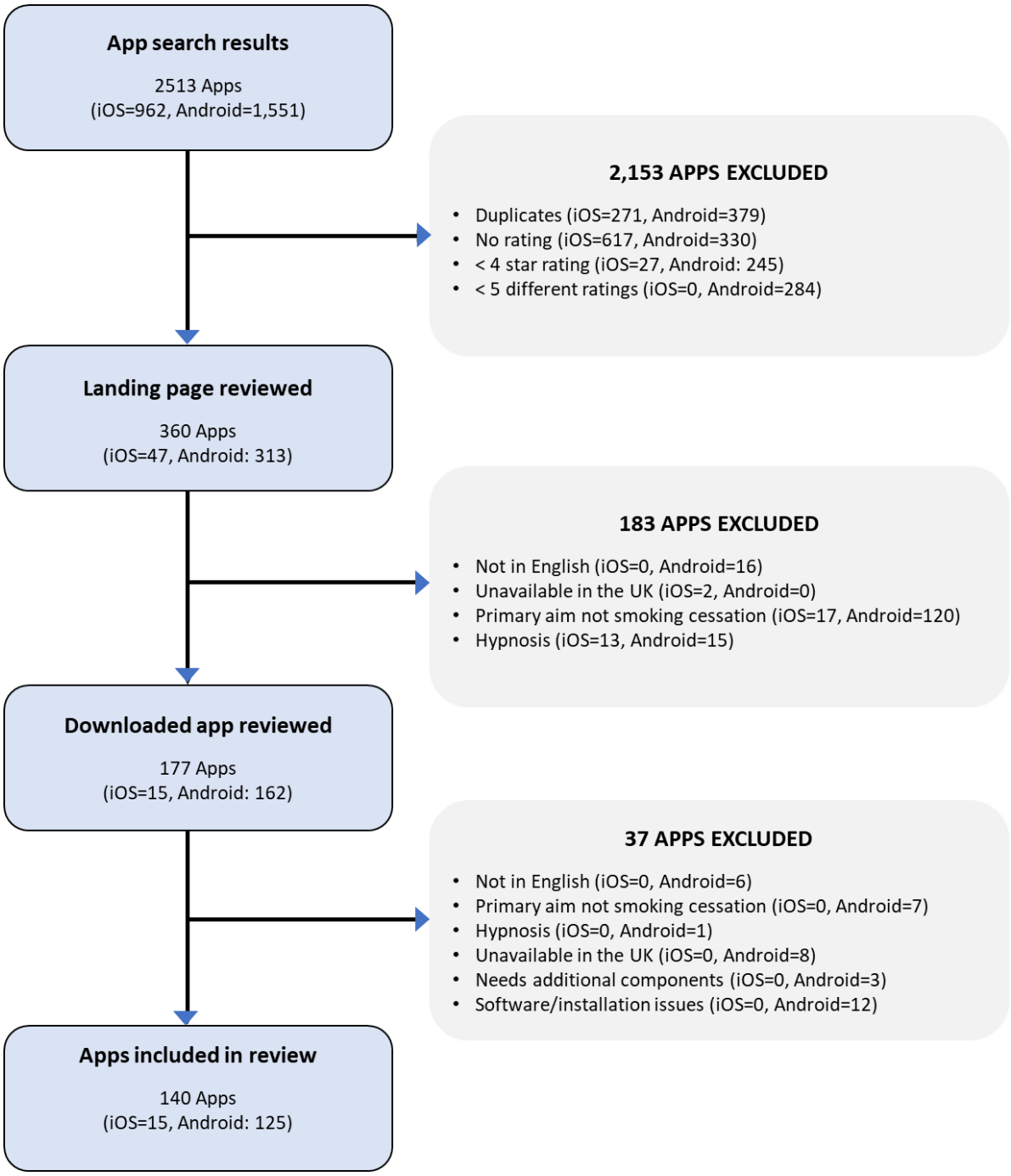
3.4 Results

3.4.1 App Search Results

The search on *42matters* using selected search terms (stop smoking, quit smoking and smoking cessation) resulted in the identification of 962 iOS and 1,551 Android apps. In total 2,153 apps were excluded after screening the data captured from *42matters*. Apps that had duplicate identification numbers, that were not rated, had less than five ratings or lower than a 4-star rating were excluded. The landing pages of the remaining 360 apps were screened, of which a further 188 apps were excluded based on the mentioned inclusion and exclusion criteria. The remaining 177 apps were downloaded and 37 of these were excluded for various reasons. For example, some were excluded due to software and installation issues whilst others were found to require additional components such as smartwatches.

After all screening was complete, 140 apps remained (15 iOS and 125 Android apps). These apps were tested to identify key app functionalities, examine adherence to smoking cessation guidelines and determine the level of gamification incorporated. Further details on the results of the app search and screening process is presented in figure 3.2.

Figure 3.2 Number of apps after each stage of the review



3.4.2 App functionalities

The key functionalities and characteristics of the smoking cessation apps available on the iOS and Android platforms is presented in table 3.3. The most common feature across both platforms was the tracker feature (86.4%) which allows app users to track the day until their quit date and/or the number of days since quitting. Another popular feature amongst apps in both platforms was the calculator feature (81.4%). The calculator feature allows users to better understand the money that they have saved as a result of quitting and/or the benefits accumulated since quitting. The tracker and calculator feature highlight the primary functionalities of smoking cessation apps available on the UK app market. On the other hand, only 11.4% of mobile apps were games or had games embedded into them to help users quit. Lastly, lung health monitoring was not present in any of the apps on the market. The table also shows that the majority of smoking cessation apps available on both platforms were free (85.0%), although several apps included upgraded versions or locked features that required payment for access. In terms of popularity, the average user rating for iOS apps was slightly higher than Android apps (4.6 vs. 4.4 out of 5) and the mean number of ratings was higher for Android compared to iOS apps.

Table 3.3 Overview of mobile apps for smoking cessation

App Characteristics		Platform		
		iOS (n=15)	**Android (n=125)**	**Both (N=140)**
App functions	Calculator	15 (100%)	99 (79.2%)	114 (81.4%)
	Rationing	1 (6.7%)	24 (19.2%)	25 (17.9%)
	Tracker	15 (100%)	106 (84.8%)	121 (86.4%)
	Informational	4 (26.7%)	18 (14.4%)	22 (15.7%)
	Game	0 (0%)	16 (12.8%)	16 (11.4%)
	Lung Health Monitor	0 (0%)	0 (0%)	0 (0%)
	Other	1 (6.7%)	4 (3.2%)	5 (3.6%)
Cost	Free	14 (93.3%)	105 (84.0%)	119 (85.0%)
	Paid	1 (6.7%)	20 (16.0%)	21 (15.0%)
	Mean Price GBP (Range)	1.0 (0.0 – 0.99)	2.2 (0.0 – 8.6)	2.1 (0.0 – 8.6)
Popularity	Mean User Rating (Range)	4.6 (4.1 – 5.0)	4.4 (4.0 – 5.0)	4.4 (4.0 – 5.0)
	Mean Number of Ratings (Range)	821 (6 – 6,500)	1,726 (6 – 35,045)	1,629 (6 – 35,045)

3.4.3 Smoking Cessation Treatment Guidelines

The total number and percentage of mobile apps adhering to evidence-based smoking cessation guidelines is displayed in table 3.4. When assessed against the Five A's, the majority of apps across both platforms *ask* users whether or not they smoke cigarettes in order to determine the smoking status of the user (84.3%). Almost half of the mobile apps (49.3%) across both platforms also *advise* users to quit smoking in a strong and clear manner. The majority of apps which *advise* and urge users to quit smoking do so by highlighting the health benefits of quitting and/or by providing positive reinforcement and encouragement to reach the decision to quit smoking.

On the other hand, adherence to the other Five A guidelines is not as high. For example, only 10.7% of mobile apps adhere to the *assess* guideline. In other words, only a few apps try to determine a smoker's willingness or readiness to make a quit attempt. Similarly, 10.0% of mobile apps across both platforms provide resources to *arrange* any follow-up contact or assistance for users. Less than a third of mobile apps (32.9%) adhered to the *assist* guideline as only a few apps provided complex and in-depth assistance to help users quit such as via a virtual quit coach, guidance on how to deal with cravings and setting a realistic quit date. The results of the chi-square tests indicate that no statistically significant differences were found between platforms for the adherence to the guidelines *ask*, *assess*, *advise* and *assist*. However, a statistically significant difference for adherence to the *arrange* guideline between the two platforms (iOS and Android) was found (p-value=.001).

Table 3.4 Number and percentage of apps adhering to Five A guidelines

Five A Guidelines	Platform			Chi-square
	iOS (n=15)	Android (n=125)	Both (N=140)	P-value
ASK	12 (80.0%)	106 (84.8%)	118 (84.3%)	.706
ADVISE	9 (60.0%)	60 (48.0%)	69 (49.3%)	.380
ASSESS	3 (20.0%)	12 (9.6%)	15 (10.7%)	.204
ASSIST	6 (40.0%)	40 (32.0%)	46 (32.9%)	.533
ARRANGE	5 (33.3%)	9 (7.2%)	14 (10.0%)	.001[a]

[a]P-value<.05

Aside from the Five A guidelines, adherence to guidelines set by the NICE institute for self-help materials for smoking cessation was also assessed (table 3.5). The majority of apps across both platforms provided information to users regarding the benefits of quitting (66.4%). The second highest adherence was to the guideline suggesting that interventions should help smokers plan a schedule (27.1%) as those apps provided users with advice on how to plan a quitting schedule, including setting a quit date and/or creating a schedule to cut down number of cigarettes smoked. Only a minority of apps adhered to the other guidelines set by NICE, particularly guidelines related to NRT products. A minority of apps provided information on the benefits of using NRT products (15.0%), the types of NRT products that are available (7.1%), how to use NRT products (2.1%) and where to get access to NRT products (2.1%).

Similar to the Five A guidelines, chi-square tests were run to test whether differences between apps on the two platforms existed. The results showed that there were no statistically significant differences between the platforms for adherence to most of the NICE guidelines for smoking cessation self-help materials. A statistically significant difference was found for the guideline which suggests that self-help materials should provide users with information on the benefits of using NRT products (p-value=.035) and for the guideline which suggests that self-help materials should provide users with information on various strategies that can be used to gradually stop or reduce the number of cigarettes smoked (p-value<.001).

Table 3.5 Number and percentage of apps adhering to NICE guidelines

NICE Guidelines for Self-Help Materials	Platform			Chi-square
	iOS (n=15)	Android (n=125)	Both (N=140)	P-value
Harm reduction	4 (26.7%)	17 (13.6%)	21 (15.0%)	.232
Benefits of quitting	11 (73.3%)	82 (65.6%)	93 (66.4%)	.773
Planning a schedule	7 (46.7%)	31 (24.8%)	38 (27.1%)	.072
Strategies to cut down	9 (60.0%)	16 (12.8%)	25 (17.9%)	.000[a]
Benefits of NRT	5 (33.3%)	16 (12.8%)	21 (15.0%)	.035[a]
Types of NRT products	3 (20.0%)	7 (5.6%)	10 (7.1%)	.076
How to use NRT products	0 (0.0%)	3 (2.4%)	3 (2.1%)	1.000
Where to get NRT products	0 (0.0%)	3 (2.4%)	3 (2.1%)	1.000
Where to get further support	1 (6.7%)	10 (8.0%)	11 (7.9%)	1.000

[a]P-value<.05

The level of adherence was identified by assessing the number of guidelines met by mobile apps across both platforms. Table 3.6 below shows that 6.4% of apps did not adhere to any of the Five A guidelines and 65.7% had low adherence (i.e. met only one or two of the guidelines). Similarly, a majority of apps also had low adherence to the guidelines set by NICE for smoking cessation self-help materials (63.6%) as they only adhered to up to three guidelines. Only 4 apps out of the 140 mobile apps tested were found to have high adherence to the evidence-based treatment guidelines specifically set out by NICE and 3 out of the 140 mobile apps were found to have high adherence to the Five A guidelines. Overall, table 3.6 shows that most of the apps available on the iOS and Android UK market did not follow treatment guidelines.

Table 3.6 Level of adherence to smoking cessation guidelines

Smoking Cessation Guidelines		**Platform**		
		iOS (n=15)	**Android (n=125)**	**Both (N=140)**
Five A Guidelines	None (0)	0 (0.0%)	9 (7.2%)	9 (6.4%)
	Low (1-2)	8 (53.3%)	84 (67.2%)	92 (65.7%)
	Medium (3-4)	6 (40.0%)	30 (24.0%)	36 (25.7%)
	High (5)	1 (6.7%)	2 (1.6%)	3 (2.1%)
NICE Guidelines for Self-Help Materials	None (0)	2 (13.3%)	31 (24.8%)	33 (23.6%)
	Low (1-3)	8 (53.3%)	81 (64.8%)	89 (63.6%)
	Medium (4-6)	4 (26.7%)	10 (8.0%)	14 (10.0%)
	High (7-9)	1 (6.7%)	3 (2.4%)	4 (2.9%)

3.4.4 Gamification

Table 3.7 displays the number and percentage of gamification strategies and gamification tactics adopted by smoking cessation mobile apps on the UK market. The most common gamification strategy present in mobile apps across both platforms was feedback on performance (91.4%). Several apps provided continuous feedback by allowing users to track the number of cigarettes smoked, number of days since quitting, health benefits accrued and/or money saved since quitting. The second most popular gamification strategy adopted by mobile apps across both platforms was goal setting. Many of the apps integrated this gamification strategy by incorporating gamification tactics (i.e. on-screen features) that allow users to set goals such as a target quit date or a target amount of savings accumulated by

refraining from smoking. Despite a large proportion of apps helping users set goals for their quit journey, only 28.6% of mobile apps included the capacity and support a user would require to achieve the goals they have set. One of the mobile apps reviewed, called *Smoking Log – Stop Smoking*, provided users with a tool to set goals with regards to the number of cigarettes smoked and/or how long users have until they are allowed to smoke their next cigarette[165]. However, the app gave no support, information or advise on how a user can realise the set goals.

Moreover, almost 50% of the mobile apps utilised the gamification strategy of social connectivity. Most of the apps integrate social connectivity by allowing users to share their achievements or progress with others via social media platforms such as Facebook and Instagram; the integration of online social communities was not common. Finally, the least adopted gamification strategy by apps on both platforms was fun and playfulness (7.9%). This finding is consistent with the low number of apps including on-screen gamification tactics such as showing game leaders (4.3%), using levels (20.0%), allocating points (7.1%) and including a theme or story within the app (4.3%). Chi-square tests showed that there were no statistically significant differences between Android and iOS smoking cessation apps with regards to gamification strategies or gamification tactics (p-value>.05).

Table 3.7 Incorporation of gamification strategies and tactics

Gamification Strategies and Tactics		Platform			Chi-square
		iOS (n=15)	Android (n=125)	Both (N=140)	P-value
Gamification Strategies	Goal setting	10 (66.7%)	80 (64.0%)	90 (64.3%)	.839
	Capacity to overcome challenges	7 (46.7%)	33 (26.4%)	40 (28.6%)	.101
	Feedback on performance	15 (100.0%)	113 (90.4%)	128 (91.4%)	.363
	Reinforcement	10 (66.7%)	61 (48.8%)	71 (50.7%)	.191
	Compare progress	4 (26.7%)	17 (13.6%)	21 (15.0%)	.242
	Social connectivity	9 (60.0%)	60 (48.0%)	69 (49.3%)	.380
	Fun and playfulness	1 (6.7%)	10 (8.0%)	11 (7.9 %)	>.999
Gamification Tactics	Provides clear goals	10 (66.7%)	80 (64.0%)	90 (64.3%)	.839
	Offers a challenge	10 (66.7%)	80 (64.0%)	90 (64.3%)	.839
	Uses levels	3 (20.0%)	25 (20.0%)	28 (20.0%)	>.999
	Allocates points	1 (6.7%)	9 (7.2%)	10 (7.1%)	>.999
	Shows progress	15 (100.0%)	113 (90.4%)	128 (91.4%)	.363
	Provides feedback	15 (100.0%)	113 (90.4%)	128 (91.4%)	.363
	Gives rewards	10 (66.7%)	61 (48.8%)	71 (50.7%)	.191
	Provides badges	9 (60.0%)	49 (39.2%)	58 (41.4%)	.122
	Shows game leaders	1 (6.7%)	5 (4.0%)	6 (4.3%)	.500
	Gives a story/theme	1 (6.7%)	5 (4.0%)	6 (4.3%)	.500

[a]P-value<.05

The level of gamification integrated into mobile apps across both platforms based on the number of gamification strategies and tactics (i.e. on-screen gamification features or elements) is displayed in table 3.8. Only 7.1% of apps did not include a single gamification strategy or tactic across both platforms. Likewise, 6.4% of apps used a high level of gamification strategies and 5.0% a high level of gamification tactics. The majority of apps adopted a medium level of gamification strategies (55.0%) by including 3 to 5 strategies out of 7 and a medium level of gamification tactics (64.3%) by incorporating 4 to 7 on-screen features out of 10. Similar to the analysis conducted with regards to adherence to smoking cessation guidelines, chi-square tests were performed and showed no statistically significant differences in the level of gamification strategies or tactics present in mobiles apps between the two platforms (p-value>.05).

Table 3.8 Level of gamification incorporated in smoking cessation mobile apps

Gamification Strategies and Tactics		Platform			Chi-square
		iOS (n=15)	Android (n=125)	Both (N=140)	P-value
Number of gamification strategies adopted	0 (None)	0 (0.0%)	10 (8.0%)	10 (7.1%)	.600
	1-2 (Low)	4 (26.7%)	40 (32.0%)	44 (31.4%)	.776
	3-5 (Medium)	9 (60%)	68 (54.4%)	77 (55.0%)	.700
	6-7 (High)	2 (13.3%)	7 (5.6%)	9 (6.4%)	.248
Number of gamification tactics adopted	0 (None)	0 (0.0%)	10 (8.0%)	10 (7.1%)	.600
	1-3 (Low)	4 (26.7%)	29 (23.2%)	33 (23.6%)	.753
	4-7 (Medium)	9 (60.0%)	81 (64.8%)	90 (64.3%)	.714
	8 -10 (High)	2 (13.3%)	5 (4.0%)	7 (5.0%)	.164

[a]P-value<.05

3.5 Discussion

3.5.1 Overview of Findings

The current study reviewed 140 smoking cessation mobile apps available publicly on the UK app market on Android and iOS app stores. To address the first objective of the study, the main functionalities and features of the apps were examined; the tracker and calculator features were identified as the most common. The second study objective was fulfilled by reviewing adherence to evidence-based cessation guidelines; the results indicated that a majority of the apps did not follow WHO Five A guidelines or NICE guidelines for smoking cessation self-help materials. Lastly, the third objective of the study was to examine the use of gamification and the results of the review found that a majority of apps integrated a medium level of gamification strategies and tactics.

3.5.2 Primary Functionalities

The most common functionality or feature present in the reviewed smoking cessation mobile apps was the tracker feature which allowed users to track the days until and/or since quitting. The calculator feature was the second most commonly present functionality and it allowed users to calculate the amount of money saved and/or the health benefits accumulated since quitting. This finding is consistent with past mobile app reviews examining smoking cessation mobile apps[147-151]. The tracker and calculator features allow users to self-monitor their progress and quit journey, which has been associated with greater effectiveness for health

behaviour change[166-168]. Self-monitoring using such features also allows users to visualise their achievements and the benefits of engaging in health behaviour change interventions, which could be motivating for users to quit and remain quit.

3.5.3 Adherence to Evidence-Based Guidelines

The review found that two thirds of mobile apps had low adherence to the Five A guidelines. Although a majority of apps *ask* users about their smoking status, only a small proportion *assess* readiness to quit, *assist* in quitting or *arrange* follow-up assistance. Research suggests that interventions which do not *assess* readiness to quit "fail to positively reinforce a crucial decision and are unable to address barriers to quitting" which in turn reduces the likelihood of smokers attaining a higher level of readiness for change[149]. This finding is in line with another mobile app review that found that only 8% of 255 smoking cessation mobile apps assessed readiness to quit and 11% arranged any type of follow-up[151].

Similar to the Five A guidelines, only 2.9% of all mobile apps tested in this review had high adherence to NICE guidelines for smoking cessation self-help materials. Whilst the majority of apps adhere to the guideline of providing information on the benefits of quitting, very few included information on NRT for smoking cessation. Since four of the NICE guidelines for smoking cessation self-help materials are related to NRT, many apps had a low level of overall adherence to the NICE guidelines. According to a systematic review, NRT is recommended as a first line of treatment for smokers seeking pharmacological help[62]; research has shown that NRT as a method of smoking cessation can increase quitting rates by up to 60%[62]. Consequently, not including information about vital cessation methods limits the effectiveness of mobile apps attempting to help smokers quit.

The low adherence to evidence-based guidelines suggests poor quality of the smoking cessation mobile apps on the market. The negative consequence of smokers using low-quality mobile apps not based on scientific guidelines could be a reduction in smokers' confidence in quitting or even continuing a quit attempt. This could, in turn hinder the pursuit of other high quality smoking cessation interventions or even stop a smoker from trying to quit at all. Moreover, the apps which were found to have high adherence to evidence-based guidelines were not necessarily the most downloaded or highest rated, which sheds further light on the

need to promote apps that are evidence-based. This could ensure that such apps remain visible and available to users in the volatile app market. As a result of these negative consequences, it is important that mobile app developers work together with public health experts and smoking cessation advisors to ensure that apps developed are in line with evidence-based guidelines. Funding streams which encourage collaboration between these stakeholders could facilitate the inclusion of public health recommendations into new mobile apps.

With regards to differences between the two operating systems, statistically significant differences were found for the *arrange* Five A guideline and for two of the NICE guidelines (e.g. providing information on strategies to cut down smoking and the benefits of NRT products). Although differences were detected, it is difficult to comment on the reliability and generalisability of these findings due to the limited sample size of the iOS apps. However, according to existing research, lower medication use was detected among Android users of a smoking cessation app compared to iOS users[169]. Whilst this does not explicitly explain why iOS apps were more likely to have information on NRT, it shows that differences between iOS and Android users can exist. Although not rigorously investigated in existing research, some surveys have reported that iOS users are more likely to have a graduate degree and belong to a higher income group compared to Android users[170]. Such sociodemographic differences between users could affect how apps are used and encourage developers to alter the content of the app based on the type of user it is targeted for. Future studies on mobile apps could explore content differences between apps on various operating systems and consider any differences when designing mobile apps and assessing their effectiveness.

3.5.4 Adoption of Gamification Features

Aside from adherence to evidence-based guidelines, the mobile app review also assessed adoption of gamification in the apps. The results indicated that a majority of smoking cessation mobile apps integrated at least one gamification strategy and/or tactic, suggesting that some gamification was present in the majority of apps. Whilst the widespread use of gamification agrees with the review of health and fitness apps by Lister et al. (2014), it is not consistent with the findings of Edwards et al. (2016) who found that only 64 (4%) of the 1680 health apps reviewed included gamification[22]. A possible explanation for this is that my

mobile app review included some gamification features that are inherently found in apps such as showing progress or providing feedback, whilst Edwards et al. (2016) considered feedback and progress tracking as behaviour change techniques rather than as gamification. The different methods of operationalising the presence of gamification is a probable explanation for the inconsistency between the two studies.

Among the apps that included gamification in my review, feedback on performance was the most frequently incorporated. Since tracker and calculator features were found to be the most common app functionalities, and such functionalities inherently provide users with continuous feedback on their quit journey, the high prevalence of the feedback on performance gamification strategy is a fitting finding. The finding is also supported by Edwards et al. (2016) as they reported that out of the 64 health apps that integrated gamification, 60 included feedback and monitoring to elicit behaviour change[22]. On the other hand, the least common gamification strategy was fun and playfulness. As a result, gamification tactics such as stories, themes or game leaders were not frequently present. It is likely that such elements are not often included in mobile apps as they are more difficult to implement compared to tracker and calculator features. The analysis of the mobile app review results also showed that 60% of mobile apps included goal setting. Goal setting has been found in existing studies to be a vital component for successful health behaviour change interventions[171]. Therefore, it is promising to see a large majority of apps including goal setting, but at the same time it is important to note that few apps provide users with advice or information on how to set goals that are realistic and achievable.

The results also showed that almost 50% of the apps incorporated the gamification strategy of social connectivity. The majority of these apps did so by providing users with an option to share results and progress via social media platforms (e.g. Facebook and Instagram). Such on-screen share features provide a basic level of social connectivity to users and are easy for app developers to implement. Very few apps attempted to integrate more complex forms of social connectivity such as online social communities. Online social communities provide a more active and engaging channel for users to share thoughts and progress with other smokers seeking to quit. Past studies have found that online social networks can positively affect health behaviour change[172-173]. Social connectivity can also serve to enhance user

engagement through the mechanism of social comparison. Social comparison occurs when individuals are able to compare and evaluate themselves against others, which in turn can impact behavioural outcomes[174]. Consequently, the gamification strategy of social connectivity could be vital in driving positive health behaviour change and be considered an important factor for the future development of health-focused mobile apps.

In terms of the overall level of gamification adopted, the review showed that the majority of apps integrated a medium level of gamification strategies and/or tactics. A small proportion of apps adopted no gamification at all or a high level of gamification. As discussed earlier, this result may be explained by the fact that certain gamification strategies, such as providing feedback or displaying progress, are inherently present in most mobile apps. For example, even apps such as Google Maps and Facebook, could be perceived as gamified when considering features such as continuous feedback and progress display. As a result of this, some previous studies examining gamification and my analysis could be detecting more frequent use of gamification. This is an important issue for future research; further work into redefining gamification taxonomies which better operationalise and measure gamification would enable researchers to understand the use of gamification elements in mobile apps, beyond those that are often inherently present.

In spite of this, there are implications for the use of gamification in mobile apps. Past studies have shown that gamification can positively affect both psychological and behavioural outcomes[23,30,120,124]. El-Hilly et al. (2016) found that smokers who used a gamified app had higher motivation to quit than those who engaged with the non-gamified app[30]. Such studies suggest that gamification can be an important component of the persuasive design and development of mobile apps. Similar to development of apps with high adherence to evidence-based guidelines, the development of apps with a high level of gamification requires collaboration between gaming experts, software developers, public health specialists focusing on smoking cessation and behaviour change experts.

Finally, it is important that technology-enabled solutions such as mobile apps are reviewed and improved as such interventions provide a relatively low-cost method of reaching a wide number of people. Past studies have found that digital interventions can have a greater

impact on individuals of lower socioeconomic status (SES) than those of higher SES[39-40]. For example, according to Brown et al. (2014), a digital smoking cessation intervention called StopAdvisor, had a greater impact on smoking cessation among individuals of low SES compared to individuals of high SES[39]. Smoking cessation was biochemically verified and measured 6 months after engagement with StopAdvisor. Unlike some previous studies, individuals of low SES demonstrated high engagement with the digital interventions[39]. Consequently, it is important that mobile apps offered to smokers seeking to quit, adhere to evidence-based smoking cessation guidelines and incorporate features such as game elements that can increase engagement and maximise possible impact. Developing and promoting more effective mobile apps for smoking cessation could possibly attenuate health inequalities by reducing smoking prevalence and increasing smoking cessation amongst disadvantaged groups.

3.5.5 Strengths, Limitations and Future Research

Aside from the operationalisation of gamification, there are other limitations of the review that should be acknowledged. For example, since apps with lower than a 4-star rating and less than five individual ratings were not included in the analysis, a large number of apps had to be excluded, especially from the Apple store. As this could have an impact on the generalisability of the findings, future reviews could include apps with lower ratings in their analyses. Lower rated apps were not included in this mobile app review in order to ensure that the number of apps which would require testing was feasible, particularly since apps from both Android and iOS platforms were included. It would also be interesting for future research to take a deeper look at app ratings and whether apps with lower ratings are associated with various levels of adherence to smoking cessation guidelines or gamification levels.

Similarly, apps that were not captured by *42matters* using the inputted search terms were not examined in the review. While apps that were excluded could differ from apps that had been included in the analysis, it is likely that the excluded apps (as a result of the screening criteria) were used by a relatively small proportion of smokers attempting to quit. It is also important to acknowledge that certain app features or functionalities which are only available or visible to users after long-term use of the app have not been identified by the study.

Although many previous mobile app reviews tested apps on only one occasion[151,153-154] , the apps in this review were tested for 30 minutes on the day of installation and 5 minutes the following day. Despite this, it is still possible that some functionalities were not identified as some gamification features or game elements may not have been visible until a certain amount of time had elapsed (e.g. badges or trophies are only visible after some days of non-smoking have been achieved). Additionally, some in-app features were not unlocked due to budgetary constraints, and therefore were not assessed in this review.

Finally, the quality of the mobile apps was not investigated as this was not the main goal of the review. However, it would be interesting for future mobile app reviews to conduct a rigorous assessment of overall app quality with validated and evidence-based tools such as the *Mobile App Rating Scale*. Further research could also examine the relationship between app quality and adherence to evidence-based cessation guidelines, as well as app quality and level of gamification[175]. Findings of such research would enhance the current understanding of the types of smoking cessation mobile apps available on the UK market and better inform app developers and health researchers during the design and development of health apps.

Despite these limitations, there are several strengths of this review. Firstly, the review focuses on apps available on the UK market with app data captured in February 2018. Only two prior mobile app reviews found in the literature examine apps on UK market and these were conducted in 2012 and 2014. Therefore, this analysis provides novel and up-to-date insight on app-based interventions available within a geographic region that has been sparsely investigated by existing studies. Another strength is the inclusion of both iOS and Android apps and the inclusion of apps with a cost. Many of the app reviews in existing literature focused on one of the two mobile platforms and were often limited to only free apps[153-154]. The inclusion of apps on Android and iOS, and apps with a cost, ensures that the findings are more representative of the UK mobile app market. Finally, this is the first study to systematically review smoking cessation mobile apps on the UK market for their integration of game elements. The findings not only inform the next stages of my research but they also lay some groundwork for future research on gamification, smoking cessation and mobile apps.

3.6 Chapter Summary

This chapter presents one of the major research outputs for my empirical investigation on the use of gamification in the context of mHealth and smoking cessation. It presents the methodology, results and implications of findings of a mobile app review examining smoking cessation apps available on the UK market. A systematic search was conducted to identify smoking cessation apps in the UK; mobile apps were assessed for primary functionalities, adherence to evidence-based guidelines and adoption of gamification elements. In total, 140 mobile apps were assessed by two reviewers. The review identified that tracker and calculator features were the most commonly present amongst smoking cessation apps. It was also found that the majority of mobile apps do not follow existing smoking cessation treatment guidelines and do not incorporate a high level of gamification. The findings can inform the choices of smokers seeking to quit, recommendations of tobacco control policymakers and design decisions of software developers. The review sheds light on the increased need for stronger collaboration between these stakeholders to develop apps that are up-to-date with treatment guidelines and which include effective strategies in order to ensure the maximum level of impact is achieved. Moreover, since gamification can address some of the limitations of mHealth solutions, such as low levels of engagement and retention, the results of this review also highlight the need for increased input from gaming experts. Future investigation into the use of gamification in apps for smoking cessation could help us better understand the role and impact of gamification on smokers seeking to quit.

Chapter Four: Stop Smoking Study Analysis with Self-Reported Data

4.1 Introduction

The importance and role of cognitive factors, such as self-efficacy and motivation to quit, for smoking cessation, is well-established in the literature[8-11,13-17]. Enhancing our understanding of methods and strategies that can positively influence such factors could lead to substantially higher quitting rates. Gamification is a strategy that has been increasingly incorporated into health apps since it shares key elements with behaviour change techniques and has easy applicability to digital solutions. Some studies have found that gamification can positively impact cognitive factors such as self-efficacy and motivation. However, to date, the majority of these studies have focused on other health behaviours, particularly physical activity and mental health[23,116,176-178].

A large proportion of studies in this subfield explore the feasibility and user acceptability of gamified mobile apps during the app development stage rather than exploring the effects of mobile apps or specific app elements on quitting or success factors associated with quitting[25-26,29]. Only a few studies have specifically investigated the impact of gamified smoking cessation mobile apps, of which many have adopted qualitative methodologies and/or suffered from relatively small sample sizes. For example, El-Hilly et al. (2016) interviewed 16 smokers in the UK and highlighted positive effects of gamification in a mobile app on motivation and engagement levels of smokers[30]. Similarly, Pløhn and Aalberg (2015) investigated the impact of a gamified smoking cessation programme among 181 participants and found positive effects of gamification on motivation and user engagement with the programme[27]. Although both studies provide some insights on the effects of gamification, they largely relied on qualitative data by analysing in-depth interviews, or in the case of Pløhn and Aalberg (2015), analyses of discussion forms and user diaries were also included[27,30].

On the contrary, Lin et al. (2018) examined 190 survey responses from users of a gamified smoking cessation app and analysed objective app usage data[143]. Through quantitative methodologies, the study found that engaging with a gamified app positively impacted

psychological factors such as user well-being, inspiration, and empowerment. Although Lin et al. (2018) adopted a quantitative methodology, it did not explore participant perception or engagement with specific gamification elements[143]. To date, no study that has quantitatively investigated whether gamification in smoking cessation mobile apps can improve self-efficacy and motivation to quit has been identified.

Based on the limitations of prior research, this study explores user engagement with gamified smoking cessation mobile apps. It aims to quantitatively investigate whether gamification embedded in cessation apps can have a positive effect on the self-efficacy and motivation to quit of smokers trying to quit. Enhancing our understanding of methods that can improve self-efficacy and motivation to quit, particularly those well-suited for digital solutions, could provide cost-effective interventions to improve quitting success and thereby alleviate the health burden of smoking.

4.2 Aims and Objectives

The primary aim of this study was to assess the association between gamification and both the self-efficacy and motivation to quit of smokers seeking to quit smoking. Specifically, the study aims to achieve the following objectives:

I. Explore whether using gamified smoking cessation mobile apps, Quit Genius or Kwit, influences the self-efficacy and motivation to quit of smokers after 2 and 4 weeks of app use.
II. Explore the perceived usefulness, ease of use and frequency of use of overall gamification and specific game elements among Quit Genius and Kwit app users.
III. Explore 7 and 28-day self-reported smoking cessation rates among Quit Genius and Kwit app users after 4 weeks of app use.
IV. Investigate the effects of perceived usefulness, ease of use and frequency of use of specific game elements and overall gamification on the self-efficacy and motivation to quit of smokers seeking to quit.
V. Investigate the association between perceived usefulness and ease of use of overall gamification and 7 and 28-day smoking cessation self-reported at the end of the study; examine the effects of frequency of use of specific game elements and overall gamification on 7 and 28-day smoking cessation self-reported at the end of the study.

4.3 Methodology

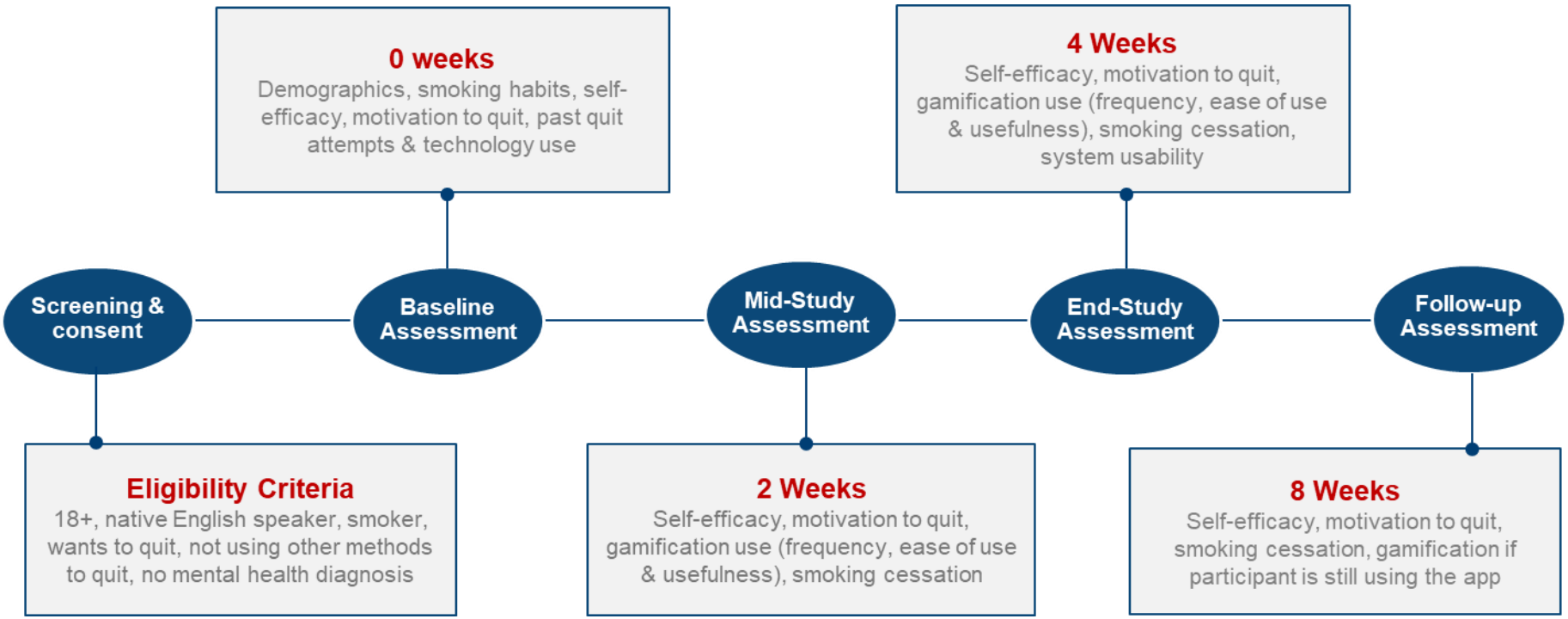
4.3.1 Study Design

A 4-week online study, called the *Stop Smoking Study* was approved by the Imperial College Research Ethics Committee (Appendix B); upon receiving ethics approval, study recruitment and enrolment took place on a rolling basis from June 2019 to July 2020. Interested participants were provided with an initial screening questionnaire to determine eligibility (Appendix C); additional details on the eligibility criteria are discussed in section 4.3.2. Eligible participants were asked to complete a consent form (Appendix D) after reading a participant information sheet (Appendix E). The participant information sheet contained information on the purpose of the study, what was expected of participants regarding their involvement, length of the study and other relevant information.

Next, participants were assigned a participant identification number (PID) and required to fill out a baseline questionnaire which included questions about general sociodemographic characteristics (e.g. age, gender, marital status and education level), current smoking habits, prior quit attempts, technology readiness, self-efficacy and motivation to quit. Upon completion of the baseline questionnaire, participants were assigned to one of two mobile apps (Quit Genius or Kwit) and asked to use the app for a duration of 4 weeks. Mobile apps were assigned to participants based on their PID; participants with even-numbered PIDs were required to use Quit Genius and participants with odd-numbered PIDs were required to use Kwit.

Participants were asked to fill out a mid-study questionnaire (2 weeks after app use) and an end-study questionnaire (4 weeks after app use) which assessed participants' self-efficacy, motivation to quit and perception of gamification use. A follow-up questionnaire was administered 8 weeks after baseline (i.e. 4 weeks after the end of the study) which assessed self-efficacy, motivation to quit, and if the apps were still being used, perception of gamification features was assessed again. Figure 4.1 provides a visual presentation of the study timeline.

Figure 4.1 Stop Smoking Study timeline



4.3.2 Participants and Setting

Smokers interested in quitting were recruited to take part in the *Stop Smoking Study*, a 4-week online study for which all data collection took place digitally with no face-to-face contact required from participants from June 2019 to July 2020. To be a part of the study, participants had to meet specific eligibility criteria. These criteria included: minimum age of 18 years, fluent in the English language, current smokers (at least 1 cigarette a day and 100 cigarettes in lifetime), willingness to quit smoking in the next 30 days, not using any other forms of smoking cessation treatments and not diagnosed with any mental health conditions.

4.3.3 Recruitment and Incentivisation

Recruitment was primarily done online via social media. Study adverts were posted on Twitter feeds, Instagram stories and Facebook groups (e.g. smoking cessation support groups and university groups). Posters advertising the study were also put-up across public places in London (e.g. community centres, gyms and restaurants). No recruitment was conducted via NHS channels or establishments (e.g. NHS hospitals, clinics or pharmacies). All recruitment material can be seen in appendix F of the thesis.

Participants were incentivised to take part in the study by offering them free access to all premium features of the smoking cessation apps Quit Genius or Kwit and a chance to win a £50 Amazon voucher. After data collection was complete, two £50 Amazon vouchers were awarded to two different participants based on a randomised draw of a PID from each app user group (Quit Genius and Kwit).

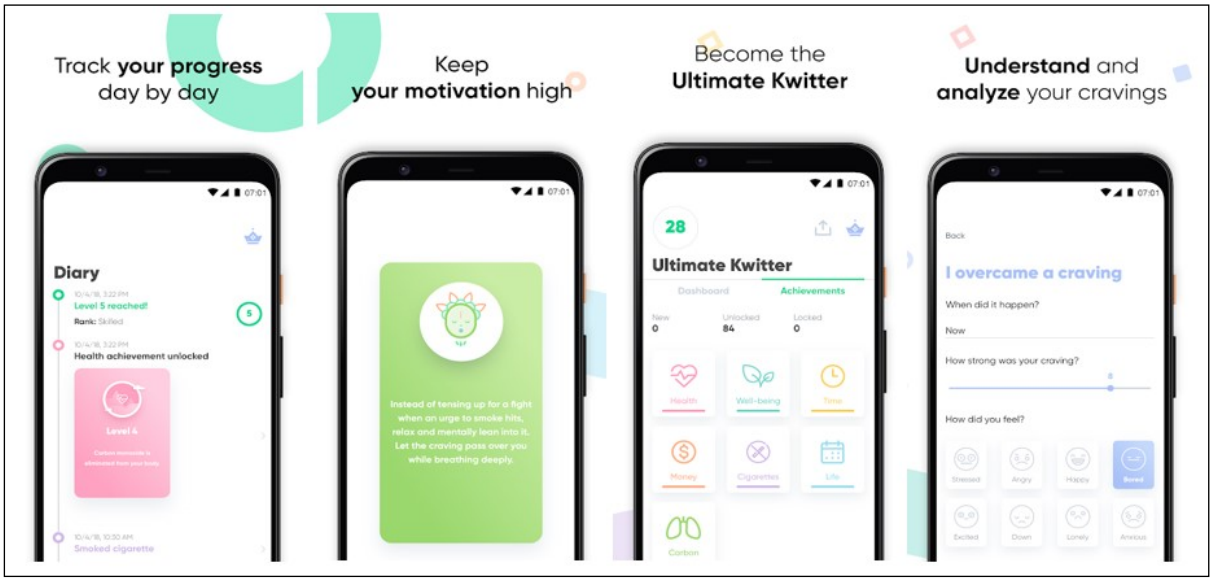
4.3.4 Mobile Apps

Quit Genius and Kwit were the two apps chosen for the *Stop Smoking Study*. The selection of these apps was based on the mobile app review presented in chapter three of this thesis, which found that both apps embedded several gamification features. As mentioned, participants were asked to use either Quit Genius or Kwit based on whether their PID was odd or even. Participants were provided app installation instructions to help them install, log-on and use the assigned mobile app (appendix G). Screenshots of both the apps can be found in the subsequent sections on each app.

Kwit

Kwit is a gamified smoking cessation mobile app that assists individuals with their quit journey and provides tools to help them stay quit[179]. The app is based on cognitive and behavioural therapy principles, positive reinforcement and gamification. It includes several features such as a calculator, tracker, motivation cards, social media sharing, a smoking diary where users can log and analyse their cravings and triggers, levels and achievement cards. Kwit also contains tools to help users tackle relapses and self-monitor to achieve quitting goals. The versions of Kwit used during the study period include those released from June 2019 (v.4.1) to July 2020 (v.4.4); screenshots of the Kwit app can be seen in figure 4.2.

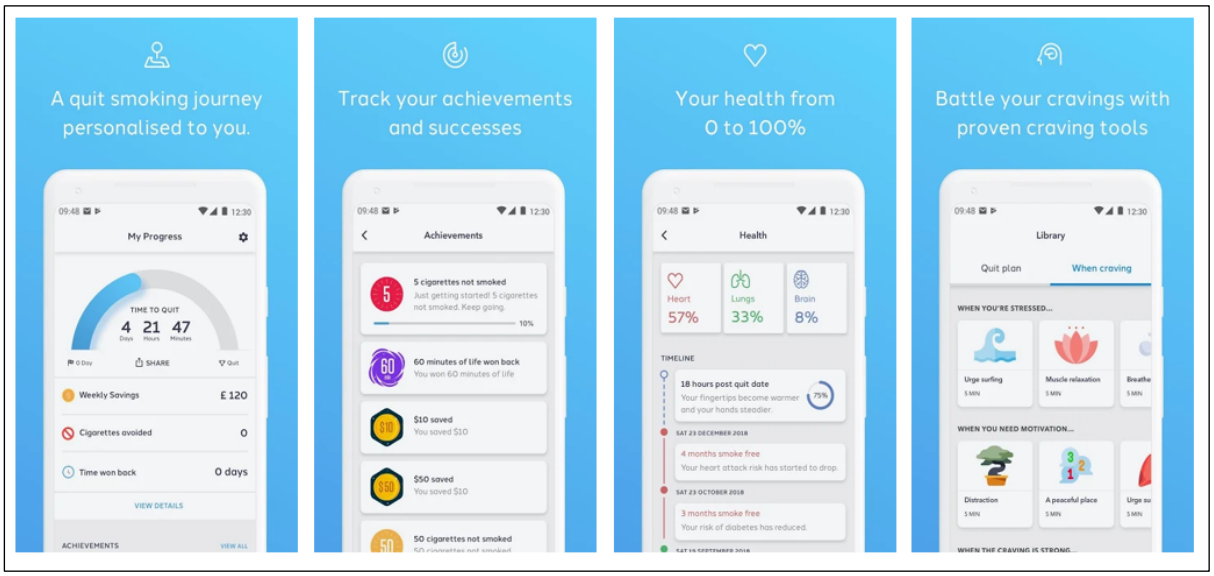
Figure 4.2 Screenshots of the Kwit app



Quit Genius

Quit Genius is a gamified smoking cessation mobile app targeting smokers seeking to quit and/or seeking to maintain their quit status[180]. It relies on cognitive behavioural therapy to deliver personalised support to users. The app includes several features such as a tracker, diary for users to log cravings and triggers, quitting toolbox, goal setting feature, achievement badges, steps that need to be completed to advance further and a quit coach that provides continuous support. The versions of the app used by participants during the study include those released from June 2019 (v.1.1) to July 2020 (v.1.9); screenshots of the Quit Genius app can be seen in figure 4.3.

Figure 4.3 Screenshots of the Quit Genius app



4.3.5 Measures

Self-Efficacy

Self-efficacy was assessed using SEQ-12 (appendix H), the 12-item Smoking Self-Efficacy Questionnaire introduced in chapter two[88]. Participants were asked how sure they were that they could refrain from smoking when faced with external stimuli such as being around other smokers or drinking alcohol (i.e. extrinsic self-efficacy) and internal stimuli such as feeling anxious or thinking about difficult problems (i.e. intrinsic self-efficacy). Answers were recorded on a 5-point Likert scale with the following options: Not at all sure, not very sure, more or less sure, fairly sure and absolutely sure. Responses were coded from 1 (not at all sure) to 5 (absolutely sure) and totalled to generate an overall self-efficacy score between 12 to 60 with higher scores signifying higher self-efficacy.

Motivation to Quit

Motivation to quit was assessed using a 2-item measure (appendix I) which has often been used in smoking cessation studies[102-104]. It examines the level of importance placed on a quitting attempt and the level of determination to successfully quit during a given quit attempt. Participants were asked, "How important is it to you to give up smoking altogether at this attempt?", for which response options included: Not all that important, quite important, very important and desperately important. Participants were also asked, "How determined are you to give up smoking at this attempt?", for which the following options

were provided: Not all that determined, quite determined, very determined and extremely determined. Responses for both items were coded from 1 to 4 and a total score ranging from 2 to 8 was calculated for each participant with higher scores signifying higher motivation.

Self-Reported Gamification

Gamification elements embedded in both apps were identified using Cugelman's framework for gamification strategies and tactics[21]. Table 4.1 shows the common and app-specific gamification elements that were identified. Both apps included smoking diaries where users could log information about their smoking status, cravings and triggers. Quit Genius awarded users with badges as they progress through their quit journey. Similarly, Kwit provided participants with achievements that could be unlocked and were awarded at different timepoints depending on how long the user stayed quit. Both apps included a *My Progress* dashboard which functioned as a tracker, allowing participants to monitor how long they have quit, how much money they saved, the health benefits accrued and time won back. Both apps also incorporated either levels or steps. Quit Genius had integrated steps that a user had to complete in order to advance to the next; each step included information on different categories such as benefits of quitting, how to cut down or how to use NRT. Similar to steps on Quit Genius, Kwit had various levels that a user could advance to after completion of information sessions and milestones achieved for staying quit. Aside from steps/levels, both apps contained a share feature which allowed users to share their progress or achievements with other people via social media. Quit Genius provided users with a lot of information on setting realistic goals on cutting down and/or quitting. Although Kwit did not have a clear goal-setting feature, it included a motivation cards feature that provided users with encouraging statements or optional activities that could boost motivation levels.

Table 4.1 Gamification elements

Quit Genius	**Kwit**
Smoking diaries	
Achievements or badges	
Progress tracking	
Levels or steps	
Sharing	
Goal setting	Motivation cards

For each of the gamification features described above, participants were asked how useful and how easy to use they perceived them. Response options included: Strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree. Perceived usefulness and ease of use are two important components of the technology acceptance model (TAM)[181]. TAM has

been widely used in existing literature to better understand user acceptance and attitudes towards mobile apps and app features[181-182]. Participants were also asked how frequently they engaged with each identified game element/feature during their quit attempt. Response options included: Almost always, often, sometimes, rarely, and never.

Responses for perceived usefulness and ease of use were coded from 1 (strongly disagree) to 5 (strongly agree) for each gamification feature. Responses for perceived frequency of use were coded from 1 (never) to 5 (almost always) for each gamification feature. A pooled mean that included all features was calculated for perceived usefulness, ease of use and frequency of use of gamification; this is referred to as *overall gamification* in this thesis. A higher mean indicated a greater level of perceived usefulness, ease of use, or engagement with the gamified features of the allocated app. The questionnaire used to measure gamification is presented in appendix J of the thesis.

Nicotine Dependence

Nicotine dependence was measured using the 6-item Fagerström questionnaire which assesses a smoker's tolerance and degree of dependence on nicotine[183]. Similar to past studies, participants were categorised into the following levels based on their responses to the questions: Low (0-4 points), moderate (5-7 points), and high (8-10 points)[183-184]. The Fagerström test for nicotine dependence is provided in appendix K.

Smoking Cessation

Similar to past studies, smoking cessation was assessed using self-report measures [27,139]. Self-reported 7-day smoking abstinence was assessed by asking participants "Have you smoked at all in the past seven days?" and 28-day point prevalence by asking "Have you smoked at all in the past 28 days?" For both measures, participants were provided with the following response options: No, not even a puff; Yes, just a few puffs; Yes, between 1 and 5 cigarettes; Yes, more than 5 cigarettes. Participants were asked about their 7-day point prevalence of smoking abstinence twice during the study (mid-study and end-study) and 28-day point prevalence of smoking abstinence once at the end of the study.

Smoking Habits and Past Quit Attempts

Participants' current smoking habits and past quit attempts were assessed at baseline. They were asked, "How many cigarettes per day do you usually smoke on a daily basis?" and were provided with the following responses: 10 or less; 11 – 20; 21 – 30; 31 or more. Additionally, "How old were you when you first started smoking cigarettes?" was part of the questionnaire for which participants could input any age. There was also a question regarding the use of other tobacco products, "Have you ever smoked or used any other forms of tobacco?" with the response options: Yes or no. Any participant that indicated "Yes" as their response was requested to select all other forms of tobacco from a list that included the following options: cigars, hand-rolled tobacco, cannabis, water pipes and chewing tobacco.

Moreover, participants were asked about their past quit attempts over the last 12 months. For example, "Have you made a serious quit attempt to stop smoking in the last 12 months? A serious attempt means you decided that you would try to make sure you never smoked again". Participants that indicated "Yes" were requested to indicate the number of quit attempts they had made. Those who reported to have made quit attempts were queried about the length of past quit attempts. Lastly, questions about use of smoking cessation methods during past quit attempts were included. For example, "Have you ever used nicotine replacement products in the past?" for which if participants indicated "Yes", they had to select the ones that applied from the following: Skin patches, chewing gum, inhalators, nasal or mouth spray, oral strips and lozenges, e-cigarettes and other. Participants were asked "Have you ever used prescribed medication to help you quit smoking in the past?". If participants indicated "Yes", they could select from the options: Zyban (bupropion), Champix (varenicline), other and prefer not to say. Finally, "Have you ever used a mobile application to help you quit smoking?" was also included in the questionnaire, for which response options included: Yes or no.

Ability to Use Smartphone Apps

Participants were asked about their ability to use smartphones with the question, "How would you rate your ability to use smartphone apps?" Participants were provided the following response choices: Excellent, good, average, poor and terrible.

System Usability Scale (SUS)

The system usability scale is a 10-item questionnaire which measures the perceived usability of a mobile app[185]. SUS contains statements about the app and provides participants with five response options which range from strongly agree to strongly disagree. The scores were converted from the original scale of 0 to 40 to a different scale ranging from 0 to 100; higher scores indicated higher perceived usability of the app. The scale is presented in appendix L.

Sociodemographic Factors

At baseline, several different sociodemographic factors such as age in years (18-29; 30-41; 42-53; 54-65), gender (male; female), marital status (single; married/civil partnered), education (low; medium; high), employment and residence were assessed. Education was categorised based on the UNESCO classification[186]. Participants were categorised as having 1) a low level of education if they completed up to primary school, 2) a medium level of education if they completed secondary school and 3) a high level of education if they attained a college or university degree. Employment was categorised into the following groups: Unemployed (i.e. individuals who are willing and able to work but have no employment), employed and non-employed (which included students, individuals who are unable to work and homemakers). Participants were asked about their country of residence; their responses were grouped based on regions set by the WHO which included: Western Pacific, Americas, South East Asia, Europe, Africa, and Eastern Mediterranean[187].

4.3.6 Sample Size

The sample size of the study was calculated based on a component of a previous study that investigated the effects of a gamified application for physical activity/fitness on perceived competence, autonomy and relatedness[178]. The outcome, perceived competence, was used as a proxy for self-efficacy to conduct an a priori analysis with a power level of $1 - \beta = 0.80$ and a significance level of $\alpha = 0.05$. The analysis indicated that approximately 112 participants would be needed to detect an effect of gamification on self-efficacy. After accounting for a dropout rate of 20% and an assumption that both apps are similar or equal, the aim was to recruit a minimum of 140 participants and have at least 112 participants complete the study. Participants were considered to have completed the study if they self-reported to engage with the app at least once a week for the duration of the study and if they completed all the required questionnaires.

4.3.7 Data Analysis

The statistical software STATA 16 was used to perform the analyses presented. Descriptive statistics were calculated to provide an overview of general participant characteristics, current smoking habits, information on past quit attempts and smoking cessation outcomes. Means and standard deviations for perceived frequency, ease of use and usefulness of specific gamification features were calculated 2 weeks (mid-study) and 4 weeks after baseline (end-study). A pooled mean for perceived frequency, ease of use and usefulness of all gamification features (referred to as overall gamification) was calculated at mid and end-study. Box and whisker plots were used to visually present means (and standard deviations) of self-efficacy and motivation to quit levels at baseline, mid-study and end-study. Due to a low response rate to the follow-up questionnaire administered at 8 weeks after baseline, follow-up data was not presented. Two-way paired sample t-tests were conducted to test statistical significance for mean differences in self-efficacy between baseline and mid-study, baseline and end-study, and mid-study and end-study. Similarly, two-way paired sample t-tests were also used to test whether mean differences in motivation to quit between the various study timepoints were statistically significant. Statistical significance for all t-tests was determined at the 5% (.05) level.

Two linear regression models were run to examine whether mean perceived usefulness, ease of use and frequency of use of overall gamification (at end-study) were associated with change in self-efficacy and change in motivation to quit. Change in self-efficacy and motivation to quit between baseline and end-study were the respective outcome variables for the models; both models controlled for age, gender, marital status, nicotine dependence, education, baseline self-efficacy and motivation to quit. A mediation analysis tested the direct and indirect effects of self-efficacy as a mediator between frequency of use of overall gamification and change in motivation to quit. Linear regression models were also used to investigate the association between perceived usefulness, ease of use and frequency of use of specific game elements (at end-study) and change in self-efficacy and motivation to quit. All models controlled for age, gender, education, marital status and nicotine dependence. Moreover, collinearity between covariates was explored for all regression models by assessing the variance inflation factor (VIF). Due to low VIF values, no further investigation was warranted.

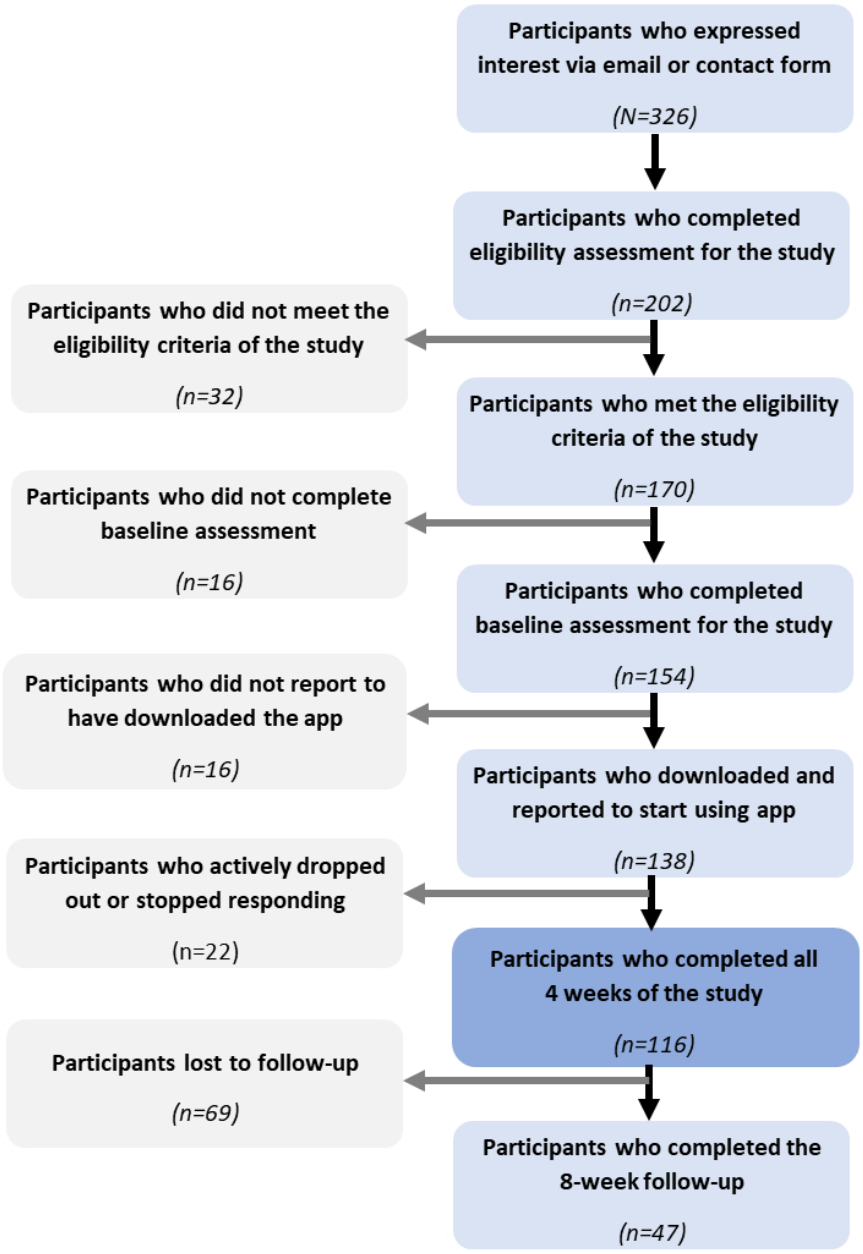
Additionally, a logistic regression model was run to test whether the odds of reporting successful 7-day smoking cessation was associated with end-study perceived usefulness, ease of use and frequency of use of overall gamification. A similar logistic regression model was run but with 28-day smoking cessation as the outcome instead. Lastly, a logistic regression model was used to investigate the association between perceived frequency of use of specific game elements and self-reported 7-day smoking cessation; the same model was also run again but with 28-day smoking cessation as the outcome variable. All logistic regression models controlled for several sociodemographic factors such as age, gender, marital status and education. All linear and logistic regression models were developed based on an iterative process which considered the fit of data with my models (i.e. comparing Akaike information criterion and Bayesian information criterion). Statistical significance was determined at the 5% (.05) level and 95% confidence intervals (CI) were presented for all coefficients and odds ratios in the models.

4.4 Results

4.4.1 Study Completion

The flowchart in figure 4.4 provides a visual representation of the number of participants that completed the different stages of the study. In total, 326 individuals expressed interest in the study via email or completion of a contact form. Among those, 202 individuals completed a questionnaire that assessed eligibility to participate in the study of which 170 individuals met the eligibility criteria. From the participants that met the eligibility criteria, 154 participants completed the assessment provided at baseline and were therefore sent the mobile app installation instructions. Of those participants, 138 reported to have installed the assigned app onto their smartphones and logged into the app with the username and password provided. In total, 116 participants completed the study (i.e. self-reported to have used the app at least once a week for all 4 weeks of the study period and completed all required questionnaires). Due to logistic and practical reasons, participants were not required to fill out the follow-up questionnaire administered 8 weeks after baseline in order for a participant to have successfully completed the study; among the 116 participants that completed the study, only 47 (40.5%) participants responded to the follow-up questionnaire.

Figure 4.4 Overview of participants from expressed interest to study completion



4.4.2 Participant Characteristics

The characteristics of the 116 participants that completed the study can be seen in table 4.2. Half of the participants that completed the study used Kwit (50.0%) and the other half used Quit Genius (50.0%). The majority of participants were male (61.2%), employed (65.6%), single (66.4%) and had a high level of education (75.0%). More than half of the participants (57.8%) reported to be residents of Europe. Moreover, the majority of participants reported to have a good to excellent ability to use smartphone apps (98.3%).

Table 4.2 Sociodemographic and general characteristics of sample (N=116)

Characteristics	Number of Respondents (N=116)	Percentage of Respondents (%)
Allocated Mobile App		
Quit Genius	58	50.0
Kwit	58	50.0
Age (Years)		
18 to 29 years	49	42.2
30 to 41 years	41	35.3
42 to 53 years	15	12.9
54 to 65 years	11	9.5
Gender		
Male	71	61.2
Female	45	38.8
Education		
Low (Primary School)	8	6.9
Medium (Secondary school)	21	18.1
High (University/College degree)	87	75.0
Marital Status		
Single	77	66.4
Married/Civil Partnered	39	33.6
Employment Status		
Employed	76	65.6
Non-Employed	31	26.7
Unemployed	6	5.2
Prefer not to answer	3	2.6
Residence (WHO Regions)		
Western Pacific	4	3.4
Americas	10	8.6
South East Asia	16	13.8
Europe	67	57.8
Africa	17	14.7
Eastern Mediterranean	2	1.7
Ability to Use Smartphone Apps		
Excellent-Good	114	98.3
Average	1	0.9
Poor-Terrible	1	0.9
System Usability Scale (0 – 100)		
Below Average	38	32.8
Above Average	78	67.2

4.4.3 Smoking Habits and Past Quit Attempts

Table 4.3 below presents information regarding smoking habits such as number of daily cigarettes smoked and dependence on nicotine. The table also includes an overview of past quitting habits of participants in the study, including whether they used other forms of cessation in the last 12 months.

Table 4.3 Smoking habits and past quit attempts in the last 12 months (N=116)

Smoking Habits and Past Quit Attempts	Number of Respondents (N=116)	Percentage of Respondents (%)
Daily Smoking (Number of Cigarettes)		
10 or less	63	54.3
11 to 20	43	37.1
21 to 30	8	6.9
31 or more	2	1.7
Fagerström Nicotine Dependence		
Low (0-4)	62	53.4
Moderate (5-7)	45	38.8
High (8-10)	9	7.8
Age (years) Started Smoking		
15 and younger	30	25.9
16 to 29	82	70.7
30 and older	4	3.4
Past Use of NRT to Quit		
No	64	55.2
Yes	52	44.8
Past Use of Medication to Quit		
No	95	81.9
Yes	21	18.1
Past Use of Mobile Apps to Quit		
No	108	93.1
Yes	8	6.9
Number of Quit Attempts		
No attempts	50	43.1
1-3 attempts	55	47.4
4-6 attempts	7	6.0
7 or more attempts	4	3.4
Smoked Other Forms of Tobacco		
No	45	38.8
Yes	71	61.2

As seen on table 4.3, a large proportion of smokers reported to smoke 10 or fewer cigarettes daily (54.3%) and a majority also smoked other forms of tobacco (61.2%). Additionally, 70.7% of participants started smoking between the ages of 16 to 29 years and a small percentage started smoking after the age of 30 years (3.4%). In terms of nicotine dependence assessed by the Fagerström nicotine dependence questionnaire, 92.2% of the participants had low to moderate dependence on nicotine. The majority of participants also reported to have tried to quit at least once in the past 12 months (56.9%). Additionally, 44.8% of participants claimed to have used NRT, 18.1% reported to have used medications (e.g. Bupropion and Varenicline) and 6.9% tried to use mobile apps to quit in the 12 months prior to data collection.

4.4.4 Self-Efficacy and Motivation to Quit

Overall, mean self-efficacy and motivation to quit levels at three different study timepoints are presented in figure 4.5: baseline (before app use), mid-study (2 weeks after baseline) and end-study (4 weeks after baseline). The box plot on the left side of figure 4.5 shows that mean motivation to quit increased from 5.94 at baseline to 6.20 after 2 weeks of app use; it increased further to 6.32 points after 4 weeks of app use. Median motivation to quit was 6.00 (IQR 5-7) at baseline, 6.00 (IQR 5-8) after 2 weeks and 7.00 (IQR 5-8) after 4 weeks of app use. Similarly, the box plot on the right side of figure 4.5 shows that mean self-efficacy increased from 37.38 points at baseline to 41.37 points after 2 weeks of app usage; it increased further to 42.47 points after 4 weeks of app use. Median self-efficacy (and IQR) was 37.00 (IQR 27-39) at baseline, 42.50 points (IQR 33-50) after 2 weeks and 44.00 (IQR 35-51) after 4 weeks of app use.

Figure 4.5 Self-efficacy and motivation to quit at baseline, mid and end-study (N=116)

Mean differences in intrinsic, extrinsic and overall self-efficacy between baseline and mid-study, mid-study and end-study, and baseline and end-study are presented in table 4.4. Increases in both sub-components and overall self-efficacy are evident between various study timepoints. After 4 weeks of using the app (end-study), intrinsic, extrinsic and overall self-efficacy increased by 2.68 (95% CI: 1.00 to 4.36), 2.41 (95% CI: 0.69 to 4.12) and 5.09 (95% CI: 1.83 to 8.34) points, respectively, compared to baseline values of 18.35, 19.03 and 37.38, respectively. Results from two-tailed paired sample t-tests showed that the increases in intrinsic, extrinsic and overall self-efficacy between baseline and mid-study, and baseline and end-study are statistically significant (p-value<.05). However, increases between mid-study and end-study were not found to be statistically significant.

Table 4.4 Paired sample t-tests examining mean differences in self-efficacy (SEQ) between study timepoints (N=116)

SEQ (Range)	**Mean Difference (95% CI) and P-value**					
	Baseline[b] vs. Mid-study[c]	P-value	Baseline vs. End-study[d]	P-value	Mid-study vs. End-study	P-value
Intrinsic (6-30)	2.22 (0.76 to 3.67)	.003[a]	2.68 (1.00 to 4.36)	.002[a]	0.47 (-0.70 to 1.63)	.430
Extrinsic (6-30)	1.78 (0.15 to 3.40)	.033[a]	2.41 (0.69 to 4.12)	.007[a]	0.63 (-0.58 to 1.84)	.305
Overall (12 to 60)	3.99 (1.16 to 6.82)	.006[a]	5.09 (1.83 to 8.34)	.003[a]	1.09 (-1.02 to 3.21)	.307

[a]P-value < .05, [b]Baseline=0 weeks (before app use); [c]Mid-study=2 weeks after app use; [d]End-study=4 weeks after app use

Similarly, table 4.5 displays mean differences in perceived importance, determination and overall motivation to quit between various study timepoints. After 4 weeks of using the app (end-study), importance, determination and overall motivation to quit increased by 0.21 (95% CI: 0.03 to 0.38), 0.17 (95% CI: 0.01 to 0.35) and 0.38 points (95% CI: 0.06 to 0.70), respectively, compared to baseline values of 3.02, 2.92 and 5.94 points. Two-tailed paired sample t-tests found that increases in perceived importance and overall motivation to quit between baseline and mid-study, and baseline and end-study were statistically significant (p-value<.05). Mean differences in importance, determination and overall motivation to quit between mid-study and end-study were not statistically significant. Likewise, mean difference

in perceived determination between baseline and mid-study (p-value=.202), and baseline and end-study was not statistically significant (p-value=.059).

Table 4.5 Paired sample t-tests examining mean differences in motivation to quit (MTQ) between study timepoints (N=116)

MTQ (Range)	Mean Difference (95% CI) and P-value					
	Baseline[b] vs. Mid-study[c]	P-value	Baseline vs. End-study[d]	P-value	Mid-study vs. End-study	P-value
Importance (1 to 4)	0.16 (0.01 to 0.30)	.033[a]	0.21 (0.03 to 0.38)	.020[a]	0.05 (-0.08 to 0.18)	.441
Determination (1 to 4)	0.10 (-0.06 to 0.26)	.202	0.17 (0.01 to 0.35)	.059	0.07 (-0.06 to 0.20)	.287
Overall (2 to 8)	0.26 (0.01 to 0.51)	.043[a]	0.38 (0.06 to 0.70)	.022[a]	0.12 (-0.10 to 0.34)	.282

[a]P-value < .05, [b]Baseline=0 weeks (before app use); [c]Mid-study=2 weeks after app use; [d]End-study=4 weeks after app use

4.4.5 Overview of Self-Reported Gamification

Apart from self-efficacy and motivation to quit, perceived use of gamification was also assessed. Table 4.6 displays the average mid-study and end-study perceived usefulness, ease of use and frequency of use of overall gamification and specific game elements embedded in the apps. At mid-study and end-study, goal setting was perceived to be the most useful gamification feature (4.14 score out of 5) whereas sharing was perceived to be the least useful feature (3.08 at mid-study and 3.28 at end-study out of 5). Similarly, participants also perceived goal setting to be the easiest feature to use at both mid-study and end-study (4.31 and 4.36 out of 5, respectively) and the sharing feature as the least easy to use at both study timepoints (3.72 out of 5). In terms of frequency of use, participants self-reported that they used the progress dashboards the most often during both the mid-study and end-study assessments (3.23 and 3.30 out of 5, respectively) followed by logging diaries (3.13 and 3.19 out of 5, respectively). The feature that was used the least frequently was the sharing feature as not many participants shared their progress or results with others.

Table 4.6 Overview of perceived usefulness, ease of use and frequency of use of gamification features embedded in Quit Genius and Kwit at mid-study and end-study (N=116)

Perceived Usefulness, Ease of use and Frequency of Use of Gamification Features	**Mid-Study**[a] Mean (SD)[c]	**End-Study**[b] Mean (SD)
Perceived Usefulness (Range: 1 to 5)		
Logging Diaries	3.78 (0.99)	3.85 (0.98)
Achievements and Badges	3.64 (1.11)	3.78 (1.06)
Progress Tracking	3.91 (0.94)	4.04 (0.93)
Unlocking Levels/Competing Steps	3.93 (0.89)	3.94 (0.93)
Sharing Feature	3.08 (1.15)	3.28 (1.17)
Motivation Cards[d]	3.64 (0.95)	3.71 (1.12)
Goal Setting[e]	4.14 (0.85)	4.14 (0.80)
Overall Perceived Usefulness	3.71 (0.75)	3.80 (0.78)
Perceived Ease of Use (Range: 1 to 5)		
Logging Diaries	4.08 (0.95)	4.07 (0.97)
Achievements and Badges	3.91 (0.96)	3.97 (1.07)
Progress Tracking	4.07 (0.86)	4.07 (0.96)
Unlocking Levels/Completing Steps	4.01 (0.94)	4.18 (0.79)
Sharing Feature	3.72 (0.87)	3.72 (0.95)
Motivation Cards[d]	4.10 (0.79)	4.08 (0.98)
Goal Setting[e]	4.31 (0.71)	4.36 (0.81)
Overall Perceived Ease of Use	4.00 (0.64)	4.04 (0.72)
Perceived Frequency of Use (Range: 1 to 5)		
Logging Diaries	3.13 (1.21)	3.19 (1.20)
Achievements and Badges	2.90 (1.27)	2.96 (1.23)
Progress Tracking	3.23 (1.11)	3.30 (1.21)
Unlocking Levels/Completing Steps	3.03 (1.02)	3.09 (1.08)
Sharing Feature	1.86 (1.13)	1.93 (1.16)
Motivation Cards[d]	2.95 (1.26)	3.14 (1.23)
Goal Setting[e]	2.64 (0.91)	2.97 (1.03)
Overall Perceived Frequency of Use	2.83 (0.80)	2.92 (0.87)

[a]Mid-study=2 weeks after app use; [b]End-study=4 weeks after app use; [c]SD=Standard deviation; [d]Applicable to Kwit; [e]Applicable to Quit Genius

4.4.6 Gamification and Self-Efficacy

A linear regression was run to investigate the association between overall mean perceived usefulness, ease of use and frequency of use of gamification after 4 weeks of app use and change in self-efficacy between baseline and end-study (table 4.7). Another model was run to investigate the association between frequency of use of specific game elements after 4 weeks of app use and change in self-efficacy between baseline and end-study (table 4.8).

Table 4.7 shows that a 1-point increase in average perceived frequency of overall gamification use was statistically significantly associated with a 3.35-point increase in change in self-efficacy from baseline to end-study (β=3.35; 95% CI: 0.31 to 6.40) after adjusting for other variables in the model. On the other hand, average perceived ease of use and usefulness of gamification were not statistically significantly associated with change in self-efficacy. In addition, a 1-point increase in baseline self-efficacy was associated with a 1.06-point decrease in change in self-efficacy between baseline and end-study (β=−1.06; 95% CI:−1.22 to −0.90). Age, gender, nicotine dependence, education, marital status and baseline motivation were not found to be statistically significantly associated with change in self-efficacy from baseline to end-study (p-value>.05).

Table 4.7 Linear regression investigating the association between perceived usefulness, ease, and frequency of use of overall gamification with change in SEQ (N=116)

Factors	**Change in Self-Efficacy**	
	β	**95% CI**
Age (years)	-0.05	-0.26 to 0.17
Gender		
Male (Referent)		
Female	1.89	-2.48 to 6.26
Nicotine Dependence		
Low (Referent)		
Moderate	-1.02	-5.50 to 3.46
High	5.93	-2.15 to 14.02
Education		
Low (Referent)		
Medium	-4.95	-15.01 to 5.16
High	-8.01	-16.63 to 0.61
Marital Status		
Single (Referent)		
Married	-0.10	-5.35 to 5.17
Mean Frequency of Gamification Use	3.35[a]	0.31 to 6.40
Mean Ease of Use of Gamification	-1.21	-5.16 to 2.74
Mean Usefulness of Gamification	1.63	-2.53 to 5.79
Baseline Self-Efficacy	-1.06[a]	-1.22 to -0.90
Baseline Motivation to Quit	1.14	-0.44 to 2.71
Constant	34.79[a]	15.68 to 53.89

[a]P-value < .05

The results of a linear regression model exploring the association between frequency of use of specific game elements and change in self-efficacy between baseline and end-study is presented in table 4.8. A 1-point increase in frequency of logging diaries was found to be statistically significantly associated with a 4.48-point increase in change in self-efficacy after 4 weeks of app use (β=4.48; 95% CI: 1.14 to 7.82). Similarly, a 1-point increase in engagement with levels/steps was statistically significantly associated with a 4.17-point increase in change in self-efficacy (β=4.17; 95% CI: 0.02 to 8.33). Frequency of unlocking achievements or badges, accessing the progress dashboard and sharing progress with others were not associated with change in self-efficacy after adjusting for other demographic factors. A linear regression model investigating perceived usefulness of specific game features found that only the levels/steps feature was associated with change in self-efficacy (appendix A, table A3). Similarly, a linear regression model investigating perceived ease of use of specific game elements did not find any significant associations with change in self-efficacy (appendix A, table A4).

Table 4.8 Linear regression model investigating the association between perceived frequency of use of individual game elements and change in SEQ (N=116)

Factors	Change in Self-Efficacy	
	β	95% CI
Age (years)	0.01	-0.33 to 0.35
Gender		
Male (Referent)		
Female	-0.02	-6.80 to 6.75
Nicotine Dependence		
Low (Referent)		
Moderate	-0.90	-7.80 to 3.46
High	1.52	-10.87 to 13.92
Education		
Low (Referent)		
Medium	7.33	-8.19 to 22.85
High	1.46	-11.89 to 14.82
Marital Status		
Single (Referent)	-0.92	-8.93 to 7.10
Married		
Frequency of Logging Diaries	4.48[a]	1.14 to 7.82
Frequency of Unlocking Achievements/Badges	-0.93	-4.85to 2.99
Frequency of Accessing Progress Dashboard	-0.80	-4.92 to 3.33
Frequency of Advancing Levels/Steps	4.17[a]	0.02 to 8.33
Frequency of Sharing Progress with Others	-1.88	-4.73 to 0.97
Constant	-15.42	-36.66 to 5.81

[a]P-value < .05

4.4.7 Gamification and Motivation to Quit

A linear regression was run to investigate the association between overall mean perceived usefulness, ease of use and frequency of use of gamification reported after 4 weeks of app use and change in motivation to quit between baseline and end-study (table 4.9). Similarly, another regression model was run to investigate the association between frequency of use of specific game elements and change in motivation to quit between baseline and end-study (table 4.10). To recap, overall mean perceived usefulness, ease of use and frequency of use of gamification at end-study was 3.80, 4.04 and 2.92 respectively (as presented in table 4.6); mean change in overall motivation to quit between end-study and baseline was 0.38 points (as presented in table 4.6).

Table 4.9 Linear regression investigating the association between perceived usefulness, ease of use and frequency of use of overall gamification with change in MTQ (N=116)

Factors	Change in Motivation to Quit	
	β	95% CI
Age (years)	-0.01	-0.04 to 0.02
Gender		
Male (Referent)		
Female	0.19	-0.37 to 0.76
Nicotine Dependence		
Low (Referent)		
Moderate	-0.08	-0.66 to 0.50
High	0.42	-0.61 to 1.46
Education		
Low (Referent)		
Medium	-1.31[a]	-2.60 to -0.01
High	-1.21[a]	-2.32 to -0.10
Marital Status		
Single (Referent)		
Married	-0.03	-0.70 to 0.65
Mean Frequency of Gamification Use	0.54[a]	0.15 to 0.94
Mean Ease of Use of Gamification	-0.03	-0.54 to 0.48
Mean Usefulness of Gamification	0.51	-0.03 to 1.04
Baseline Self-Efficacy	-0.02	-0.02 to -0.00
Baseline Motivation to Quit	-0.69[a]	-0.90 to -0.49
Constant	3.19[a]	0.73 to 5.65

[a]P-value < .05

Table 4.9 shows that having a medium or high level of education was associated with a 1.31-point (95% CI −2.60 to −0.01) and 1.21-point (95% CI:−2.32 to −0.10) decrease in change in motivation to quit compared to individuals with a low level of education. Moreover, a 1-point increase in average perceived frequency of use of gamification features was statistically significantly associated with a 0.54-point increase in change in motivation to quit at end-study compared to baseline (β=0.54; 95% CI: 0.15 to 0.94). There was also some indication that the average usefulness of overall gamification and baseline self-efficacy are associated with change in motivation to quit. Additionally, a 1-point increase in baseline motivation to quit was statistically significantly associated with a 0.69-point decrease in change in motivation to quit (β=−0.69; 95% CI:−0.90 to −0.49). A mediation analysis found that change in self-efficacy

partially mediates or explains the relationship between frequency of overall gamification use and change in motivation to quit (appendix A, table A5 and figure A1).

Table 4.10 Linear regression model investigating the association between perceived frequency of individual game element use and change in MTQ (N=116)

Factors	Change in Motivation to Quit	
	β	95% CI
Age (years)	-0.01	-0.05 to 0.19
Gender		
Male (Referent)		
Female	0.24	-0.43 to 0.92
Nicotine Dependence		
Low (Referent)		
Moderate	-0.19	-0.88 to 0.50
High	-0.10	-1.33 to 1.14
Education		
Low (Referent)		
Medium	-0.70	-2.24 to 0.85
High	-0.75	-2.08 to 0.58
Marital Status		
Single (Referent)		
Married	-0.36	-1.16 to 0.44
Frequency of Logging Diaries	0.26	-0.07 to 0.59
Frequency of Unlocking Achievements/Badges	-0.24	-0.63to 0.15
Frequency of Accessing Progress Dashboard	0.01	-0.40 to 0.42
Frequency of Advancing Levels/Steps	0.54[a]	0.13 to 0.96
Frequency of Sharing Progress with Others	0.17	-0.12 to 0.45
Constant	-0.48	-2.60 to 1.64

[a]P-value < .05

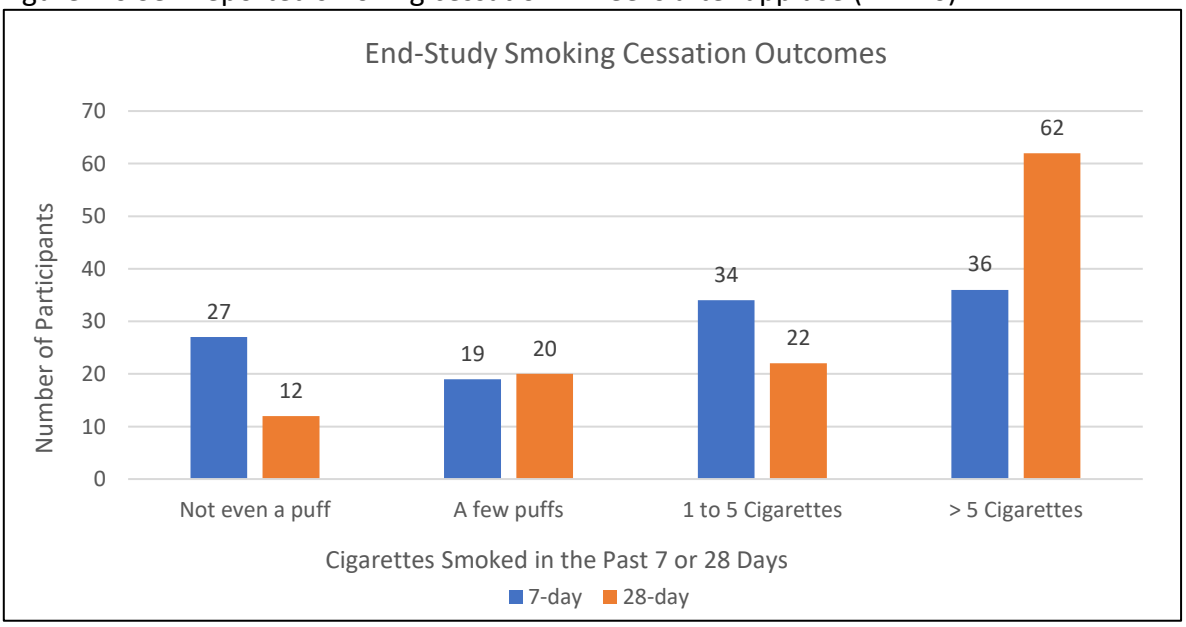
Table 4.10 shows that a 1-point increase in frequency of engaging with the levels/steps feature was statistically significantly associated with a 0.54-point increase in change in motivation to quit after 4 weeks of app use (β=0.54; 95% CI: 0.13 to 0.96). Frequency of logging diaries, unlocking achievements or badges, accessing the progress dashboard and sharing progress with others were not found to be associated with change in motivation to quit after adjusting for other demographic factors. Perceived usefulness of all the individual game elements were not found to be associated with change in overall motivation to quit (appendix A, table A6). Similarly, aside from logging diaries, perceived ease of use for the

various gamification elements were not found to be statistically significantly associated with change in overall motivation to quit (appendix A, table A7).

4.4.8 Gamification and Smoking Cessation

The following results section focuses on quitting rates of both Quit Genius and Kwit users. Figure 4.6 presents an overview of 7 and 28-day self-reported smoking cessation for all study participants. In total, 23.28% of all participants reported to have successful 7-day smoking cessation at the end of the study and 16.38% of participants reported to have smoked only a few puffs. The 28-day smoking cessation rates were lower with 10.34% of participants reporting at the end of the study that they did not smoke a cigarette in the last 28 days. Moreover, 17.24% of participants reported that they smoked only a few puffs in the past 28 days. Logistic regression models found that average perceived usefulness, ease of use and frequency of use of gamification were not statistically significantly associated with 7 or 28-day smoking cessation self-reported at the end of the study. These models are presented in appendix A (tables A8 and A9).

Figure 4.6 Self-reported smoking cessation 4 weeks after app use (N=116)



With regards to perceived frequency of use of specific features of the app, a logistic regression model, presented in table 4.11, found that a 1-point increase in engagement with the levels/steps feature of the app was associated with more than twice the odds of reporting 7-day smoking cessation at the end of the study after adjusting for engagement with other

features and several sociodemographic factors (OR=2.37; 95% CI: 1.13 to 4.98). Frequency of engagement with specific game elements were not found to be associated with 28-day smoking cessation (appendix A, table A10).

Table 4.11 Logistic regression investigating the association between perceived frequency of individual game element use and self-reported 7-day smoking cessation (N=116)

Factors	7-Day Smoking Cessation	
	Odds Ratio	**95% CI**
Age (years)	0.95	0.89 to 1.00
Gender		
Male (Referent)		
Female	1.52	0.51 to 4.57
Nicotine Dependence		
Low (Referent)		
Moderate	1.61	0.54 to 4.80
High	1.29	0.16 to 10.24
Education		
Low (Referent)		
Medium	9.41	0.61 to 145.29
High	5.63	0.47 to 67.78
Marital Status		
Single (Referent)		
Married	5.88	1.54 to 22.53
Frequency of Logging Diaries	0.87	0.51 to 1.48
Frequency of Unlocking Achievements/Badges	1.53	0.79 to 2.97
Frequency of Accessing Progress Dashboard	0.86	0.41 to 1.81
Frequency of Advancing Levels/Steps	2.37[a]	1.13 to 4.98
Frequency of Sharing Progress with Others	0.89	0.58 to 1.36
Constant	0.01	0.00 to 0.24

[a]P-value < .05

4.5 Discussion

4.5.1 Overview of Findings

The analysis of the self-reported data indicate that use of the two gamified smoking cessation apps positively influenced self-efficacy and motivation to quit 4 weeks after app use compared to baseline (objective I). The increase in self-efficacy and motivation to quit

occurred primarily during the first 2 weeks of app use and then remained fairly stable. Additionally, the increases were not found to be associated with age, gender, marital status and nicotine dependence, suggesting that the apps had a similar effect on participants regardless of such characteristics.

The second objective of this study was to explore participant perception of overall gamification and specific game elements in the two apps. The study demonstrated that goal setting was perceived to be the most useful and easiest to use feature, whilst accessing the progress dashboard was the most frequently used feature both 2 weeks and 4 weeks after app use (objective II). The sharing feature was perceived to be the least useful, easy to use and frequently used. With regards to exploring smoking cessation outcomes, the study found that approximately 23% of participants reported successful 7-day cessation and 10% reported 28-day cessation at the end of the study (objective III).

Regression models revealed that perception of how frequently participants engaged with gamification features was significantly associated with change in self-efficacy and motivation to quit. Specifically, perceived frequency of logging diaries was associated with an increase in change in self-efficacy and engaging with the levels/steps feature was found to be associated with both an increase in change in self-efficacy and motivation to quit (objective IV). Unlike self-efficacy and motivation to quit, perceived frequency of engagement with overall gamification was not associated with 7-day cessation at the end of the study. However, when investigating the effects of specific game elements, greater perceived frequency of engagement with the levels/steps feature increased the odds of reporting successful 7-day cessation (objective V).

4.5.2 Self-Efficacy and Motivation to Quit Before and After App Use

One of the main findings of the study was the statistically significant increase in overall self-efficacy and motivation to quit between baseline and end-study. Increase in self-efficacy implies that participants experienced a higher level of perceived confidence in their ability to refrain from smoking. Higher motivation to quit implies greater perceived determination to quit and higher importance placed on a given attempt. Keeping gamification aside, these findings are consistent with several past studies that investigated the impact of mobile apps

for smoking cessation[30, 188-189]. For example, Hoeppner et al. (2019) conducted a single-group pilot study of 30 participants testing the impact of a mobile app with positive psychology exercises to support smoking cessation[189]. Similar to my findings, Hoeppner et al. (2019) found that participants had higher self-efficacy levels 2 weeks after using the app compared to baseline[189]. Likewise, El-Hilly et al (2018) found that participants who used the mobile app Quit Genius experienced greater motivation to quit after using the app[30]. However, as previously discussed, El-Hilly et al (2018) suffered from a small sample size, only asked users to engage with the app for a single week and adopted a purely qualitative methodology[30].

The positive impact of the mobile apps on self-efficacy and motivation to quit is an important finding for smokers seeking to quit as higher self-efficacy and motivation to quit are associated with increased odds of successfully quitting and staying quit[8,10,15,97]. According to Piñeiro et al. (2016), motivation is a vital ingredient during the quitting process because it enhances a smoker's intention to quit[15]. Likewise, self-efficacy has been found to be associated with better quitting outcomes because of its influence on a smoker's coping behaviours when experiencing withdrawal symptoms or cravings[87].

My analysis also showed that a large proportion of the increase in self-efficacy and motivation to quit was evident during the first 2 weeks of app use; after 2 weeks, self-efficacy and motivation to quit levels plateaued. This could mean that the apps have a saturated effect after 2 weeks, implying that the initial weeks of app use act as a ramp-up phase. Another study by Schnoll et al (2011) found that among participants who engaged in a 12-week long smoking cessation intervention, those who experienced an increase in self-efficacy during the first 2 weeks had a greater likelihood of staying quit after treatment[95]. This could highlight the importance of promoting self-confidence early-on during cessation interventions in order to improve the odds of successfully quitting. Consequently, future smoking cessation interventions could try to adopt strategies that have a strong effect on cognitive factors such as self-efficacy and motivation, particularly during the early stages of the intervention. Although it remains unclear why this may be, it would be interesting to investigate whether the introduction of new strategies or features could lead to a continued increase rather than the maintenance of self-efficacy and motivation to quit levels.

Another important finding was that no association between age, gender, marital status and nicotine dependence with change in overall self-efficacy and motivation to quit was found. This could suggest that both apps had a similar effect on participants regardless of these factors. However, since the majority of the study sample was male, highly educated, single and had low to moderate dependence on nicotine, this finding may not be generalisable. Whilst the sample size was adequate to detect effects of gamification, relatively small sub-group sample sizes may have reduced the study's power to detect subgroup differences in effectiveness.

Furthermore, the analyses showed that having higher baseline self-efficacy and motivation to quit was associated with smaller increases in self-efficacy and motivation to quit between baseline and end-study. This suggests that the mobile apps had a greater impact on individuals with lower confidence and determination during the quitting process. The apps are likely to have a decreasing marginal benefit on users, implying that every additional increase in baseline self-efficacy and motivation to quit would result in a smaller benefit to the user as change is more difficult to achieve. On the other hand, having lower baseline levels prior to using the app would mean that the users have more room for improvement. The findings also showed that a lower level of education was associated with an increase in change in motivation to quit. By using education as a proxy for SES, this finding could suggest that individuals with lower SES are more likely to experience a greater benefit from engaging with the apps. In order to effectively inform future interventions with the goal of reducing health inequalities, additional research would need to be conducted to understand why this was the case. It could be that the apps and other types of behaviour change interventions have a natural ceiling effect – a maximum possible level of impact that they can achieve. The further away a participant is from the *ceiling* effectiveness of an app, the more room for there is for change and improvement.

4.5.3 Gamification, Self-Efficacy and Motivation to Quit

With regards to the impact of overall gamification, analyses showed that perceived frequency of overall gamification use was associated with both an increase in change in self-efficacy and motivation to quit after 4 weeks of app use compared to baseline. There are a few plausible theories that could explain the positive effect of self-reported use of the gamification

features. One explanation could be that interacting with game elements enhanced user engagement with the mobile apps, which in turn positively influenced self-efficacy and motivation to quit. A systematic review by Looyestyn et al. (2017) found that gamification effectively enhanced user engagement with digital interventions[190]. Similarly, Kamal et al. (2019) found positive effects of gamification in a fitness smartphone app called *Play4fit* on user engagement[145]. Therefore, it is possible that frequency of gamification use influenced overall user engagement with the app, which in turn positively influenced self-efficacy and motivation to quit. Another possible explanation could be that the game elements made the app more rewarding and enjoyable for users regardless of the final outcome. According to the theory of flow, people are able to experience a state called flow, when they are highly involved in an activity because it is enjoyable and would therefore engage with it even at a cost[191]. This type of unconditional engagement facilitated by game elements could explain the positive impact on self-efficacy and motivation to quit.

Aside from overall gamification, analyses examining specific game elements showed that logging diaries was associated with an increase in change in self-efficacy. Similarly, engaging with incremental levels/steps was associated with an increase in both self-efficacy and motivation to quit between baseline and end-study. It is possible that logging diaries of overcoming cravings and viewing them as a way to track and signal progress could have positively impacted self-efficacy. Alternatively, it could be that levels/steps and diaries allow participants to stay informed about their progress during a quit attempt, facilitating perceptions that their goal is attainable and low-risk, which can boost confidence and motivation levels[107]. This explanation can be further supported by the theory of self-determination which states that motivation can be fostered through the fulfillment of different psychological needs: autonomy, competence and relatedness[192]. Based on this theory, it is possible that by providing immediate feedback on performance through game elements such as level advancement and progress tracking via smoking diaries, the competence needs of smokers seeking to quit are fulfilled, thereby leading to improved self-efficacy and motivation levels.

The effects of perceived gamification on self-efficacy and motivation to quit demonstrated by the analyses can have important implications for the use of gamification and game design

principles in non-game contexts. For example, although perceived frequency of use and perceived usefulness of the steps/levels was found to be associated with improved confidence and motivation to quit during a quit attempt, it is not a feature that is commonly adopted by smoking cessation mobile apps. According to the results of the mobile app review presented in chapter three of my thesis, unlocking levels or completing steps was a feature that was only adopted by 20% of the apps reviewed. The lower levels of adoption of gamification features that participants reported to be the most useful during their quit attempts, highlights the need for collaboration between mobile app developers, scientists and smokers in order to develop digital interventions that are evidence-based but still cater to the needs and wants of smokers seeking to quit.

4.5.4 Strengths, Limitations and Future Research

By investigating the effects of gamified smoking cessation apps quantitatively, this study addresses a gap in the current literature. But to do so, a questionnaire to quantitatively assess gamification was developed and data was collected via self-report. The use of self-reported data can be a limitation as it could lead to different or inaccurate perceptions among participants. This can particularly be an issue when interpreting responses to questions regarding frequency of use. Personal expectations with regards to perceived frequency can play a role since what is considered to be frequent for one participant may not be for another. Participant perception of frequency of use could also be influenced by how memorable participants found those features to be. Additionally, the questionnaire used to assess gamification has not been scientifically validated. Whilst it provides a good starting point for researchers, a natural progression for further research would be to refine and validate the questionnaire so that it could be easily applied to a variety of settings and contexts. The collection and analysis of in-app data, also known as logged data, would be a useful way to address the limitations of self-reporting, particularly with regards to understanding frequency of use or engagement. The analysis of in-app data to supplement the current findings, and exploration of differences between self-reported and in-app data is presented in the next chapter of my thesis (chapter five).

Aside from the operationalisation of gamification, there are also some limitations of the study sample. For example, the majority of participants in the study had low to moderate nicotine

dependence which could affect baseline self-efficacy and/or motivation to quit levels. It is also likely that individuals that signed up for the study were already motivated to quit and this may not be representative of all smokers. Similarly, since individuals with mental health conditions were excluded from participating, and the majority of the sample was male, educated and resided in Europe, it could be that the findings are not applicable to all population groups. Replicating the study with different types of smokers, such as high nicotine dependent smokers or smokers with mental health conditions, could lead to some interesting comparisons and findings. Moreover, recruiting a more diverse sample in future studies would improve the external validity of the findings and provide more insights on the impact of gamification in smoking cessation mobile apps on different population groups.

It is also important to acknowledge the methodological limitations of the study. For example, participants were assigned to use one of two mobile apps in the study. But in reality, smokers would naturally self-select interventions available on their mobile app stores. Additionally, since not enough follow-up data was collected due to low response rates at the 8-week study mark, the long-term impact of the mobile apps was not investigated. Future studies could explore whether effects of mobile apps are sustained for a longer period of time and how they may compare to face-to-face cessation interventions.

Despite these limitations, the findings of this study build upon the current understanding of the impact of smoking cessation apps and can provide a basis for the design of RCTs. RCTs could consider including two smoking cessation apps that are as similar as possible, differing only in the number or type of gamification elements. Future studies could also try to isolate and test the effects of individual game elements, as different gamification elements may not have the same impact or function in the same way. It is likely that some gamification elements interact with other elements and/or with individual dispositions, situational circumstances or characteristics of particular target activities differently than others[22]. It could also be that the effects of gamification are only evident when multiple game elements are present to target behavior change more effectively. Although there are several possible avenues and unanswered questions for future studies to address, this study provides a good basis to build upon as it adds to the current knowledgebase on the role of gamification for smoking cessation in mobile apps.

4.6 Chapter Summary

Chapter four presents the objectives, methodology and results of a study that is a major component of this doctorate thesis. Smokers seeking to quit participated in a 4-week remote study during which they were asked to use one of two gamified smoking cessation apps and fill out questionnaires at various study timepoints. The study found that the assessed mobile apps positively influenced the self-efficacy and motivation to quit of smokers making quit attempts. Moreover, gamification embedded into the mobile apps was associated with improvements in self-efficacy and motivation to quit. Despite some of the limitations, such as the use of self-reported data, this study has important implications for the future use of digital interventions and how they might influence critical factors for the quitting process. The findings of this study can also provide insights for mobile app developers, tobacco control policy makers, behaviour change specialists and smokers seeking to quit.

Chapter Five: Stop Smoking Study Analysis with In-App Metrics

5.1 Introduction

The previous chapter of this thesis (chapter four) analysed self-reported data to investigate whether gamified smoking cessation mobile apps can influence the self-efficacy and motivation to quit of smokers seeking to quit. Although self-reporting is an important data collection technique that can provide useful insights, research shows that it can be prone to biases[193-194]. For example, individuals may have different perceptions of frequency, respond in ways that would be viewed as socially desirable or lack the ability to recall behaviours that they would not normally think about[194]. In-app data, often referred to as logged data in the literature, is more objective and can address some of the limitations of self-reporting.

Whilst the use of in-app data to supplement self-report is often recommended, it is not commonly done by existing studies as in-app data can be difficult, expensive and time consuming to obtain. Mobile app studies on smoking cessation that do include objective app engagement data often include general metrics such as the number of times an app was opened, the amount of time spent on an app or level of programme completion[143]. Only one study was found in the context of smoking cessation mobile apps that included in-app engagement data on the use of specific app features[195]. However, no self-reported app engagement data was included in the study. According to the literature, self-reported and in-app data ought to both be used when feasible as they provide different and complementary insights, resulting in a more complete and thorough understanding of engagement[193, 196-198]. Consequently, this chapter presents an exploratory analysis of in-app metrics to supplement the findings presented in chapter four that focused solely on self-reported data. In this chapter, in-app metrics are analysed to gain a better understanding of the role of gamification in influencing important cognitive factors associated with smoking cessation and to explore the differences between in-app and self-reported data.

5.2 Aims and Objectives

As a result of the lack of studies incorporating in-app data in the context of smoking cessation, gamification and mHealth, this exploratory analysis aims to explore user engagement with gamified mobile apps for smoking cessation using in-app metrics. More specifically, the analysis aims to fulfil the following objectives:

I. Explore user engagement with the gamified smoking cessation mobile apps Quit Genius and Kwit using in-app metrics.
II. Investigate the association between engagement with Quit Genius and Kwit using in-app metrics and the self-efficacy and motivation to quit of smokers seeking to quit.
III. Investigate the association between engagement with Quit Genius and Kwit using in-app metrics and 7-day self-reported smoking cessation.
IV. Compare self-reported and in-app data on engagement with gamification elements in the mobile apps Quit Genius and Kwit.

5.3 Methodology

5.3.1 Study Overview

The collection and analysis of in-app metrics presented in this chapter was part of the *Stop Smoking Study* conducted between June 2019 and July 2020. The previous chapter of this thesis (chapter four) describes the methodology of the study in detail. To summarise and recap, smokers seeking to quit smoking were recruited primarily via social media to participate in a remote study for which they were asked to engage with gamified smoking cessation mobile apps and answer some questionnaires. Eligible participants were assigned identification numbers which were used to allocate them to one of two gamified smoking cessation mobile apps: Quit Genius or Kwit[179-180]. Participants were asked to use the assigned app for 4 weeks and to fill out a questionnaire 2 weeks after app use (mid-study) and 4 weeks after app use (end-study). At these study timepoints, participants were asked about their self-efficacy, motivation to quit, perceived engagement with app features and cessation outcomes. App developers shared in-app metrics for engagement with the app overall and specific features for each identification number that I shared with them. Participants were incentivised to take part in the study with free access to all features of the app and a chance to win a £50 Amazon voucher.

5.3.2 Measures

Self-Efficacy

As mentioned in chapter four, self-efficacy was measured using SEQ-12, the 12-item scale that assesses an individual's confidence in their ability to refrain from smoking[88]. SEQ-12 includes a 5-point Likert scale with the following responses: not at all sure (1), not very sure (2), more or less sure (3), fairly sure (4) and absolutely sure (5). A total score was calculated ranging from 12 to 60 with higher scores indicating higher overall self-efficacy. The SEQ-12 questionnaire can be seen in appendix H.

Motivation to Quit

Motivation to quit smoking was measured using a 2-item measure frequently used in past studies[15, 102-103]. Participants were asked: How important is it to you to give up smoking altogether at this attempt? Responses included: desperately important, very important, quite important and not all that important. Participants were also asked: How determined are you to give up smoking at this attempt? Responses included: extremely determined, very determined, quite determined and not all that determined. Responses for both questions were coded and totalled, resulting in a range from 2 to 8 with a higher score indicating a higher motivation to quit. The motivation to quit questionnaire can be seen in appendix I.

Smoking Cessation

Smoking cessation was assessed using self-report measures. 7-day point prevalence of smoking abstinence was assessed by asking participants, "Have you smoked at all in the past seven days?" Participants were asked to choose from the following response options: No, not even a puff; Yes, just a few puffs; Yes, between 1 and 5 cigarettes; Yes, more than 5 cigarettes. If the response was "No, not even a puff", participants were categorised as successful quitters. In the analyses presented, all other responses to the question were categorised as not successful in achieving 7-day smoking cessation.

App Engagement: Self-Reported

Self-reported engagement with app features was based on questions that asked participants how frequently they engaged with each gamification element/feature during their quit attempt. Participants were provided with 5-point Likert scale responses: Almost always, often, sometimes, rarely and never. Responses were assigned points ranging from 1 to 5 for

each gamification feature. Further details on self-reported app engagement can be found in chapter four (section 4.3.5) and the self-reported questionnaire assessing engagement with gamification is also included in appendix J.

App Engagement: In-App Metrics

Prior to the study, it was predetermined that in-app metrics would be used to better understand engagement with gamification features and also to ensure that participants had used the app. During the planning stage of the study, it was agreed upon with the app developers that a range of different metrics would be extracted and shared with me. However, due to technical issues with the collection of metrics on the side of the app developers, only a fraction of this data was available at the end. For example, some metrics related to gamification features (e.g. time spent on achievements/badges screen, time spent on progress dashboard etc.) which were expected to be part of the analyses of this study were not successfully collected. Similarly, specific inputs by app users, such as their logged cravings and triggers or their smoking status were also not successfully collected and therefore could not be a part of the analyses.

After preliminary comparison between in-app and self-reported data, some obvious discrepancies between them were identified. For example, for some participants, in-app data showed that no minutes were spent on the app or the app was opened only a few times. However, this was cross-checked with participants who claimed that they did use the app. The app developers were consulted regarding the contradictory data and it was determined that there could have been technical errors that may have caused some of the discrepancies. Regardless, participants that were found to have spent no minutes on the app or did not open the app at least four times according to the in-app data were excluded from the analysis. A minimum cut-off point of four was utilised based on an assumption that the participants did not engage with the app at least once a week for 4 weeks as instructed. The in-app metrics that were shared by the developers of the two apps can be seen in table 5.1.

Table 5.1 Shared in-app metrics from Quit Genius and Kwit

In-App Metric	Quit Genius	Kwit
Number of times app was opened	✓	✓
Time spent on the app (minutes)	✓	✗
Number of steps/levels completed	✓	✓
Number of diaries logged	✓	✓
Number of shares made	✓	✗
Number of accesses of cravings toolbox	✓	✗
Number of times quit date was changed	✓	✗
Number of motivation cards viewed	✗	✓
Number of achievements unlocked	✗	✓

The number of diaries in both apps refers to a count of the number of smoking diaries a user had logged onto the app. Smoking diaries allowed users to log daily smoking statuses, cravings (and their intensity level) and triggers. For Quit Genius, the number of steps refers to the various stages or steps completed by a user; each step provided information on various aspects of smoking cessation and to complete a step or a stage in Quit Genius, users had to read some information and move closer to achieving the set quitting goal. For Kwit users, the equivalent of steps was the levels feature; Kwit contains 28 levels and users would need to complete one level to move on to the next. An app user could advance to the next level if they achieved certain milestones (e.g. not smoking for a certain number of days). Quit Genius developers provided the number of shares which refers to the number of times participants shared any progress (e.g. achieving a new level or obtaining a badge) with someone else using the share function (via social media or text message). Quit Genius also provided the number of times cravings toolbox was accessed and the number of times quit date (goal setting) was changed. On the other hand, Kwit provided information on the number of motivation cards viewed; motivation cards could be “opened” by app users and these cards contained messages to motivate the user to continue their quit journey. Kwit also included information on the number of achievements unlocked. There are 72 achievements in the Kwit app which a participant can unlock; each achievement is associated with a specific category (e.g. health, well-being, money, time, cigarettes and carbon dioxide levels).

5.3.3 Data Analysis

The statistical software STATA 16 was used for the analysis. Descriptive statistics (e.g. number and percentage of participants) were used to present the general characteristics of the participants included in the analyses of this chapter and those participants that were excluded (based on engagement with the app determined by in-app metrics). Differences between the included and excluded participants were compared using Pearson chi-square tests for independence. For frequency counts of less than five, Fisher's exact test of independence was conducted and statistical significance was determined at the 5% level (.05). Additionally, the number and percentage of participants that self-reported successful 7-day cessation at the end of the study was presented; however, 28-day smoking cessation was not presented or used in the analyses due to the small sample sizes for each app. Mean and standard deviation values for self-efficacy and motivation to quit were calculated at baseline and end-study for Quit Genius and Kwit users separately. Two-way paired sample t-tests were used to test whether the differences between baseline and end-study were statistically significant; significance levels were set at the 5% level (.05) and 95% confidence intervals were presented.

To provide an overview of the level of engagement with the apps Quit Genius and Kwit, mean and standard deviations were calculated for the in-app metrics that were successfully collected and shared by the app developers. Two-way paired sample t-tests were conducted to test statistically significant differences in engagement metrics between baseline and mid-study, and mid-study and end-study among Quit Genius users; significance levels were set at the 5% level (.05). The same comparison for Kwit users could not be made as only aggregate 4-week data was available.

Linear regression models were used to test the association between frequency of engagement with the apps (based on in-app metrics) and change in self-efficacy for Quit Genius users and Kwit users. The same models were run again but with change in motivation to quit as the outcome variable. Logistic regression models were used to test whether associations between app usage metrics and 7-day self-reported cessation were present after controlling for age and gender among Quit Genius and Kwit users. Significance levels were set at the 5% level (.05) and 95% confidence intervals were presented for all coefficients and odds ratios. For all linear and logistic regression models, both the unadjusted and adjusted

coefficients or odds ratios were presented. Variables included in the models were chosen based on an iterative process which considered the fit of the data with the models by comparing Akaike information criterion and Bayesian information criterion. For Quit Genius regression models, the in-app data on the sharing feature and access of the toolbox were not included because too few participants used these features. Since almost all the participants used the goal-setting feature, this was also not included in the regression models with data from Quit Genius users.

Collinearity between covariates in the models was explored using variance inflation factors (VIFs). For the regression models among Quit Genius users, there was some indication of collinearity between the number of times the app was opened and the amount of time spent on the app. In order to be consistent with the regression models for Kwit users, the amount of time spent on the app was not included as a covariate in any of the models except one logistic regression model (exploring smoking cessation) due to conceptual reasons. For the regression models for Kwit users, there was some indication of collinearity between the number of achievements unlocked and the number of levels advanced. However, it was decided that both covariates would remain in the models as removing either one of the two from the models did not alter the main conclusions derived from the analyses.

Finally, an exploratory analysis to compare in-app data with self-reported data was done by the creation of scatterplots on STATA 16. Outliers present in the in-app metrics were excluded in the scatterplots for better visualisation (i.e. 2 outliers for Quit Genius data and 2 outliers for Kwit data). Pairwise Pearson correlation coefficients of self-reported and in-app data were calculated to understand the strength and statistical significance of any correlations found; similar to the other analyses presented in the thesis, statistical significance was determined at the 5% level (.05).

5.4 Results

5.4.1 Study Sample

Among the 116 participants that completed the study, the in-app data for 89 participants was included in this analysis. This is because 14 participants that used the Kwit app were excluded as the in-app data showed that they opened the Kwit app less than four times over the study period. Additionally, 13 participants that were allocated to use the Quit Genius app were excluded because the in-app data indicated that they spent no time engaging with the app. The models presented in chapter four which examined the association between engagement with the gamified apps (based on self-report) and change in self-efficacy and motivation to quit were run again with only the participants that were found to have engaged with the app based on the in-app metrics explored in this chapter (n=89). Since the findings of the re-run models (n=89) were generally consistent with the models presented in chapter four with the entire study sample (n=116), it is assumed that the conclusions remain valid whether or not the 27 excluded participants truly engaged with the app. Additionally, table 5.2 provides a brief summary of the key characteristics of the sub-sample of participants included in the subsequent analyses (n=89) and of the participants that were excluded due to not meeting engagement requirements (n=27). The majority of participants that were included in the analyses presented in this chapter were male (59.6%), highly educated (74.2%), employed (62.9%) and single (67.4%). Chi-square test results indicated that apart from employment status, there were no statistically significant differences between the two groups of participants.

Table 5.2 Overview and comparison of participants that were included in this sub-analysis (n=89) and those that were excluded (n=27)

Characteristics	Participants		Chi-square
	Included (n=89)	Excluded (n=27)	P-value
Allocated Mobile App			
Quit Genius	45 (50.6%)	13 (48.1%)	.826
Kwit	44 (49.4%)	14 (51.9%)	
Age (Years)			
18 to 29 years	37 (41.6%)	12 (44.4%)	
30 to 41 years	30 (33.7%)	11 (40.7%)	.427
42 to 53 years	14 (15.7%)	1 (3.7%)	
54 to 65 years	8 (9.0%)	3 (11.1%)	
Gender			
Male	53 (59.6%)	18 (66.7%)	.506
Female	36 (40.4%)	9 (33.3%)	
Education			
Low (primary/secondary school)	6 (6.7%)	2 (7.4%)	
Medium (high school)	17 (19.1%)	4 (14.8%)	.928
High (university/college degree)	66 (74.2%)	21 (77.8%)	
Marital Status			
Single	60 (67.4%)	17 (63.0%)	.668
Married/Civil Partnered	29 (32.6%)	10 (37.0%)	
Employment Status			
Employed	56 (62.9%)	20 (74.1%)	
Non-Employed	25 (28.1%)	1 (3.7%)	.000[a]
Unemployed	6 (6.7%)	0 (0.0%)	
Prefer not to answer	2 (2.2%)	6 (22.2%)	
Nicotine Dependence			
Low	49 (55.1%)	13 (48.2%)	
Moderate	33 (37.1%)	12 (44.4%)	.841
High	7 (7.9%)	2 (7.41%)	

[a]P-value < .05 = Statistically significant

5.4.2 Self-Efficacy and Motivation to Quit

Quit Genius

Mean self-efficacy and motivation to quit at baseline (i.e. before app use) and end-study (i.e. 4 weeks after app use) is presented in table 5.3. The table also includes the mean difference between baseline and end-study, tested by a paired-sample t-test. The results show that mean self-efficacy increased by 6.2 points 4 weeks after using Quit Genius compared to baseline; this difference was statistically significant (p-value=.013). The mean motivation to quit level increased by 0.4 points 4 weeks after using Quit Genius compared to before the app was used; however, the difference was not statistically significant (p-value=.084).

Table 5.3 Self-efficacy and motivation to quit among Quit Genius users (n=45)

Self-efficacy and Motivation to Quit	**Mean (SD)**[a]		**Mean Difference (95% CI)**
	Baseline	End-study	Baseline vs. End-study
Self-efficacy (Range: 12-60)	37.8 (13.5)	44.0 (10.6)	6.2 (1.4 to 11.0)[b]
Motivation to Quit (Range: 2-8)	6.0 (1.4)	6.4 (1.7)	0.4 (-0.1 to 1.0)

[a]SD = Standard deviation; [b]P-value < .05 = Statistically significant

Kwit

Mean self-efficacy and motivation to quit at baseline, end-study and between the two study timepoints among Kwit users is presented in table 5.4. The results show that the mean self-efficacy level increased by 5.6 points (p-value=.056) 4 weeks after using Kwit compared to baseline. The mean motivation to quit level increased by 0.5 points (p-value=.054) 4 weeks after using Kwit compared to before the app was used. Differences in self-efficacy and motivation to quit were both borderline non-significant.

Table 5.4 Self-efficacy and motivation to quit among Kwit users (n=44)

Self-efficacy and Motivation to Quit	**Mean (SD)**[a]		**Mean Difference (95% CI)**
	Baseline	End-study	Baseline vs. End-study
Self-efficacy (Range: 12-60)	36.6 (11.8)	42.2 (10.7)	5.6 (-0.1 to 11.3)
Motivation to Quit (Range: 2-8)	5.8 (1.4)	6.3 (1.7)	0.5 (-0.0 to 1.0)[b]

[a]SD = Standard deviation; [b]P-value < .05 = Statistically significant

5.4.3 Mobile App Use

In-app metrics for both Quit Genius and Kwit users were analysed to better understand the level of actual engagement participants had with their assigned app. Although not all in-app metrics were obtained, a summary of those which were shared are presented in table 5.5 for Quit Genius users (n=45) and in table 5.6 for Kwit users (n=44).

Quit Genius

Table 5.5 displays the mean in-app metrics for Quit Genius users between baseline and mid-study (0 to 2 weeks of app use), mid-study to end-study (2 to 4 weeks of app use) and overall during the entire study period (0 to 4 weeks). Quit Genius was opened on average 43.1 times during the 4 weeks of app usage and 85.8 minutes were spent by participants on average engaging with the app over the course of the study. Participants spent more time on the app during the first 2 weeks (67.7 minutes) compared to during the last 2 weeks (18.1 minutes) of the study. Although more time was spent on the app during the first 2 weeks of the study, the app was opened more often during the last 2 weeks of the study. Additionally, on average approximately 29 steps were completed and around 10 diaries were logged during the study period. Participants also logged more diaries and completed more steps during the first 2 weeks of the study (baseline to mid-study) compared to the last 2 weeks (mid-study to end-study). Paired sample t-tests found that the mean differences in the number of steps completed, the amount of time spent on the app and the number of diaries logged during the first 2 weeks compared to the last 2 weeks of app use were statistically significant.

Table 5.5 Summary of in-app metrics for Quit Genius users from 0 to 2 weeks, 2 to 4 weeks and throughout the entire study (n=45)

In-App Metrics	Mean (SD)[a]			T-test
	Baseline to Mid-study (0 to 2 weeks)	Mid-study to End-study (2 to 4 weeks)	Baseline to End-study (0 to 4 weeks)	P-value
Number of times the app opened	18.9 (20.8)	24.2 (77.2)	43.1 (92.4)	.592
Number of minutes spent on the app	67.7 (62.7)	18.1 (20.0)	85.8 (74.4)	.000[b]
Number of steps completed by the user	23.7 (33.1)	5.2 (11.3)	28.9 (35.2)	.001[b]
Number of smoking diaries logged	7.4 (9.2)	2.8 (5.7)	10.2 (13.6)	.000[b]
Number of times quit date was changed	2.3 (3.1)	1.1 (1.8)	3.4 (4.3)	.005[b]
Number of times share feature was used	0.0 (0.0)	0.0 (0.1)	0.0 (0.1)	.323
Number of times toolbox was accessed	1.2 (2.2)	0.3 (1.1)	1.5 (2.7)	.017[b]

[a] SD = Standard deviation; [b] P-value < .05 = Statistically significant

Kwit

Table 5.6 displays a summary of in-app metrics for Kwit users. On average, Kwit users opened the app almost 31 times over the 4-week study period. Among the metrics that were collected, on average the most frequently used features in the Kwit app were logging of smoking diaries (22.8 times) and unlocking of achievements (22.3 times). Additionally, over the 4-week study period, motivation cards were opened on average 8 times and approximately 8 levels were unlocked by Kwit users.

Table 5.6 Summary of in-app metrics for Kwit users during 4 weeks of app use (n=44)

In-App Metric	Mean (SD)[a] at End-Study
Number of Times App Opened	30.8 (39.0)
Number of Motivation Cards	8.0 (11.2)
Mean Number of Achievements Unlocked	22.3 (16.5)
Number of Diaries Logged	22.8 (49.3)
Number of Levels	7.7 (4.9)

[a]SD = Standard deviation

5.4.4 Mobile App Use and Change in Self-Efficacy

The results of regression models examining the association between engagement with either Quit Genius or Kwit (based on in-app metrics) and change in self-efficacy between baseline and end-study are presented below in tables 5.7 (Quit Genius) and 5.8 (Kwit).

Quit Genius

The mean change in self-efficacy between baseline and end-study (i.e. before app use and 4 weeks after app use) among Quit Genius users is 6.2 points (as presented earlier in table 5.2). Table 5.7 below presents the results of a linear regression model investigating the association between engagement with Quit Genius features and change in self-efficacy between baseline and end-study. Every additional step completed on the app is associated with a 0.12-point statistically significant increase in change in self-efficacy between baseline and end-study after adjusting for all other variables in the model (Adjusted β=0.12, 95% CI: 0.03 to 0.21). Moreover, every 1-point increase in baseline self-efficacy is associated with a 0.85-point decrease in change in self-efficacy between baseline and end-study after adjusting for all other variables in the model (Adjusted β=-0.85, 95% CI: -1.09 to -0.62). Finally, no statistically significant associations were found between the number of times the app was opened and the number of diaries logged with change in self-efficacy. Change in self-efficacy was also found to be consistent regardless of age and gender.

Table 5.7 Linear regression investigating the association between use of Quit Genius and change in self-efficacy between baseline and end-study (n=45)

Factors	Change in Self-Efficacy (SEQ)			
	Unadjusted[a] β	95% CI	Adjusted[b] β	95% CI
Age (Years)	0.14	-0.29 to 0.57	0.00	-0.28 to 0.28
Gender				
Male (Referent)				
Female	2.39	0.63 to -7.51	2.64	-3.88 to 9.15
No. of times app opened	-0.03	-0.08 to 0.02	-0.02	-0.06 to 0.11
No. of steps completed	0.11	-0.02 to 0.25	0.12[c]	0.03 to 0.21
No. of diaries logged	0.30	-0.06 to 0.65	0.14	-0.10 to 0.37
Baseline self-efficacy	-0.90[c]	-1.14 to -0.66	-0.85[c]	-1.09 to -0.62
Constant	6.2	1.36 to 11.04	33.4	17.68 to 49.14

[a]Unadjusted = Coefficient of regression model with no other covariate; [b]Adjusted = Coefficient of regression model adjusted for other covariates; [c]P-value < .05 = Statistically significant

Kwit

As seen on table 5.8, each additional level advanced in the Kwit app was significantly associated with a 1.31-point increase in change in self-efficacy between baseline and end-study (Unadjusted β=1.31, 95% CI: 0.18 to 2.46). Similarly, each additional motivation card opened was statistically significantly associated with a 0.60-point increase in self-efficacy between baseline and end-study (Unadjusted β=0.60, 95% CI: 0.11 to 1.09) and every additional achievement unlocked was statistically significantly associated with a 0.45 point increase in change in self-efficacy between baseline and end-study (Unadjusted β=0.45, 95% CI: 0.12 to 0.77). However, once the model adjusts for other covariates, the in-app metrics are no longer statistically significantly associated with change in self-efficacy. The adjusted regression model shows that a 1-point increase in baseline self-efficacy is associated with a 1.31-point decrease in change in self-efficacy between baseline and end-study (Adjusted β=-1.31, 95% CI: -1.63 to -0.99).

Table 5.8 Linear regression investigating the association between use of Kwit and change in self-efficacy between baseline and end-study (n=44)

Factors	**Change in Self-Efficacy (SEQ)**			
	Unadjusted[a] β	**95% CI**	**Adjusted[b] β**	**95% CI**
Age (Years)	-0.25	-0.81 to 0.33	-0.08	-0.43 to 0.28
Gender				
Male (Referent)				
Female	0.57	-11.37 to 12.51	3.69	-3.61 to 11.00
No. of times app opened	-0.00	-0.15 to 0.15	0.04	-0.20 to 0.28
No. of diaries logged	-0.04	-0.16 to 0.08	-0.01	-0.19 to 0.18
No. of motivation cards	0.60[c]	0.11 to 1.09	-0.06	-0.41 to 0.28
No. of achievements	0.45[c]	0.12 to 0.77	0.79	-0.12 to 1.70
No. of levels advanced	1.31[c]	0.18 to 2.46	-2.20	-5.26 to 0.85
Baseline self-efficacy	-1.37[c]	-1.63 to -1.11	-1.31[c]	-1.63 to -0.99
Constant	5.59	-0.15 to 11.33	53.29[c]	37.76 to 68.82

[a]Unadjusted = Coefficient of regression model with no other covariate; [b]Adjusted = Coefficient of regression model adjusted for other covariates; [c]P-value < .05 = Statistically significant

5.4.5 Mobile App Use and Change in Motivation to Quit

The results of regression models examining the association between engagement with either Quit Genius or Kwit (using in-app metrics) and change in motivation to quit between baseline and end-study are presented in tables 5.9 (Quit Genius) and 5.10 (Kwit).

Quit Genius

The mean change in motivation to quit between baseline and end-study (i.e. before app use and 4 weeks after app use) among Quit Genius users is 0.4 points (as presented earlier in table 5.2). Table 5.9 below presents the results of a linear regression model investigating the association between engagement with Quit Genius features and change in motivation to quit between baseline and end-study. The number of times the app was opened, the number of steps completed and the number of diaries logged were not found to be statistically significantly associated with change in motivation to quit between baseline and end-study; this is consistent for both the adjusted and unadjusted model. Changes in motivation to quit were also found to be consistent regardless of age and gender. Additionally, every 1-point increase in baseline motivation to quit is associated with a 0.43-point decrease in change in motivation to quit after adjusting for the other factors in the model (Adjusted β=-0.43, 95% CI: -0.78 to -0.09).

Table 5.9 Linear regression investigating the association between use of Quit Genius and change in motivation to quit between baseline and end-study (n=45)

Factors	Change in Motivation to Quit			
	Unadjusted[a] β	95% CI	Adjusted[b] β	95% CI
Age (Years)	0.02	-0.03 to 0.06	0.00	-0.04 to 0.04
Gender				
Male (Referent)				
Female	0.87	-0.13 to 1.87	0.84	-0.16 to 1.84
No. of times app opened	-0.00	-0.01 to 0.00	-0.00	-0.01 to 0.00
No. of steps completed	0.01	-0.01 to 0.02	0.01	-0.00 to 0.02
No. of diaries logged	-0.00	-0.04 to 0.03	-0.00	-0.04 to 0.04
Baseline motivation to quit	-0.46[c]	-0.81 to -0.13	-0.43[c]	-0.78 to -0.09
Constant	0.44	-0.06 to 0.95	2.39	-0.53 to 5.31

[a]Unadjusted = Coefficient of regression model with no other covariate; [b]Adjusted = Coefficient of regression model adjusted for other covariates; [c]P-value < .05 = Statistically significant

Kwit

Table 5.10 shows that each the number of times the app was opened, smoking diaries logged, motivation cards opened, achievements unlocked and levels achieved were not statistically significantly associated with change in motivation to quit between baseline and end-study adjusted for age, gender and baseline self-efficacy. Similarly, change in motivation to quit was consistent regardless of age and gender. These findings are consistent for both the unadjusted and adjusted regression model. Only baseline motivation to quit is statistically significantly associated with change in motivation to quit whether or not the model adjusts for other covariates.

Table 5.10 Linear regression investigating the association between use of Kwit and change in motivation to quit between baseline and end-study (n=44)

Factors	Change in Motivation to Quit			
	Unadjusted[a] β	95% CI	Adjusted[b] β	95% CI
Age (Years)	-0.03	-0.08 to 0.02	-0.03	-0.08 to 0.02
Gender				
Male (Referent)				
Female	-0.34	-1.39 to 0.72	0.30	-0.81 to 1.42
No. of times app opened	-0.00	-0.00 to 0.17	0.03	-0.01 to 0.07
No. of diaries logged	-0.00	-0.01 to 0.01	-0.03	-0.05 to 0.00
No. of motivation cards	0.03	-0.01 to 0.78	0.02	-0.03 to 0.07
No. of achievements	0.01	-0.02 to 0.05	0.06	-0.08 to 0.20
No. of levels advanced	0.03	-0.07 to 0.14	-0.18	-0.65 to 0.29
Baseline motivation to quit	-0.47[c]	-0.82 to -0.12	-0.54[c]	-0.94 to -0.15
Constant	0.50[c]	-0.01 to 1.01	4.11[c]	1.61 to 6.62

[a]Unadjusted = Coefficient of regression model with no other covariate; [b]Adjusted = Coefficient of regression model adjusted for other covariates; [c]P-value < .05 = Statistically significant

5.4.6 Mobile App Use and Smoking Cessation

The number and percentage of participants that report successful 7-day cessation at the end of the study is presented in table 5.11. Around 24% of Quit Genius and 30% of Kwit users reported at the end of the study that they had not smoked a single puff in the last seven days. Further statistics on smoking cessation outcomes, specifically 28-day cessation are presented in chapter four (section 4.4.8) of this thesis. However, for the analysis presented in this chapter, only 7-day smoking cessation is considered due to small app-specific sample sizes.

Table 5.11 Overview of 7-day self-reported smoking cessation 4 weeks after using Quit Genius (n=45) or Kwit (n=44)

	Quit Genius Users		Kwit Users	
7-Day Cessation	**Number of Smokers (N=45)**	**Percentage of Smokers (%)**	**Number of Smokers (N=44)**	**Percentage of Smokers (%)**
Success	11	24.4	13	29.6
Failure	34	75.6	31	70.5

Quit Genius

Table 5.12 shows a logistic regression model investigating the impact of Quit Genius on 7-day self-reported smoking cessation after 4 weeks of app usage. It can be seen that every 10-minute increase in time spent on the app is statistically significantly associated with a 25% greater likelihood of achieving 7-day self-reported smoking cessation after controlling for other factors in the model (Adjusted OR: 1.25, 95% CI: 1.04 to 1.51). Moreover, every additional smoking diary logged by the user is statistically significantly associated with a 21% lower likelihood of reporting successful 7-day cessation (Adjusted OR: 0.79, 95% CI: 0.65 to 0.98). On the other hand, the number of times the app was opened and the number of steps completed were not associated with 7-day cessation at the end of the study.

Table 5.12 Logistic regression investigating the association between Quit Genius use and 7-day self-reported smoking cessation after 4 weeks of app use (n=45)

Factors	**Unadjusted OR[a] (95% CI)**	**Adjusted OR[b] (95% CI)**
Age (Years)	0.96 (0.90 to 1.03)	0.84 (0.73 to 0.98)[c]
Gender		
Male (Referent)		
Female	0.72 (0.18 to 2.94)	1.05 (0.17 to 6.68)
Amount of time on app (per 10 minutes)	1.09 (1.00 to 1.19)	1.25 (1.04 to 1.51)[c]
No. of steps completed	1.02 (1.00 to 1.04)	1.01 (1.0 to 1.04)
No. of diaries logged	0.94 (0.87 to 1.03)	0.79 (0.65 to 0.98)[c]
No. of times app opened	0.99 (0.99 to 1.01)	0.99 (0.98 to 1.00)

[a]Unadjusted = Odds ratio of regression model with no other covariate; [b]Adjusted = Odds ratio of regression model adjusted for other covariates; [c]P-value < .05 = Statistically significant

Kwit

The results of a logistic regression model exploring the association between engagement with the Kwit app using in-app metrics and odds of reporting successful 7-day cessation at the end of the study are presented in table 5.13. Each additional achievement unlocked is significantly associated with almost 50% increased likelihood of achieving 7-day smoking cessation after controlling for other factors in the model such as age and gender (Adjusted OR: 1.49, 95% CI:1.02 to 2.17). The number of smoking diaries logged, motivation cards opened, levels unlocked and the number of times app was accessed were not statistically significantly associated with 7-day smoking cessation in the adjusted model. However, in the unadjusted model, the number of levels completed by Kwit users was associated with almost a 20% increased likelihood of reporting successful 7-day smoking cessation (Unadjusted OR: 1.19, 95% CI: 1.01 to 1.39).

Table 5.13 Logistic regression investigating the association between Kwit use and 7-day self-reported smoking cessation after 4 weeks of app use (n=44)

Factors	Unadjusted OR[a] (95% CI)	Adjusted OR[b] (95% CI)
Age (Years)	1.00 (0.94 to 1.07)	0.97 (0.90 to 1.05)
Gender		
Male (Referent)		
Female	0.99 (0.26 to 3.74)	3.80 (0.53 to 27.35)
No. of times app accessed	0.99 (0.98 to 1.01)	1.01 (0.96 to 1.08)
No. of smoking diaries logged	0.99 (0.97 to 1.02)	0.94 (0.85 to 1.04)
No. of motivation cards opened	1.04 (0.99 to 1.10)	1.01 (0.93 to 1.10)
No. of achievements unlocked	1.06 (1.01 to 1.12)[c]	1.49 (1.02 to 2.17)[c]
No. of levels completed	1.19 (1.01 to 1.39)[c]	0.33 (0.10 to 1.11)

[a]Unadjusted = Odds ratio of regression model with no other covariate; [b]Adjusted = Odds ratio of regression model adjusted for other covariates; [c]P-value < .05 = Statistically significant

5.4.7 Comparison of In-App Metrics with Self-Reported Data

In order to explore and compare in-app data (actual use of gamification features) with self-reported data (perceived use of gamification features), scatter plots were created. The scatter plots were used to further explore the data and gain a better understanding of the relationship between perception of use and actual use. A summary of the self-reported data for perceived frequency of use of gamification features can be found in chapter four (section 4.4.5).

Quit Genius

For the Quit Genius app, comparisons between self-reported and in-app data were only possible for two of the features (figure 5.1): number of diaries logged and number of steps completed. In figure 5.1a, a reasonable trend can be visually observed between the in-app data and self-reported data since app users who claimed to log a high number of diaries also logged more diaries according to in-app data. Although not strong, a statistically significant positive correlation between the two types of data was identified ($r=0.37$, p-value=.013). On the other hand, the correlation between self-reported perceived frequency of completing steps and the number of steps completed according to in-app data was weak (figure 5.1b). According to a pairwise correlation, no statistically significant correlation between the in-app and self-reported data for completion of steps was found ($r=0.25$, p-value=.091). Additionally, some discrepancies between the two types of data are visible. For example, many app users that claim to have interacted with the steps feature "rarely/seldom" were also users that engaged with the feature more frequently than expected according to in-app metrics.

Figure 5.1 Comparison of in-app metrics with self-reported data for Quit Genius users

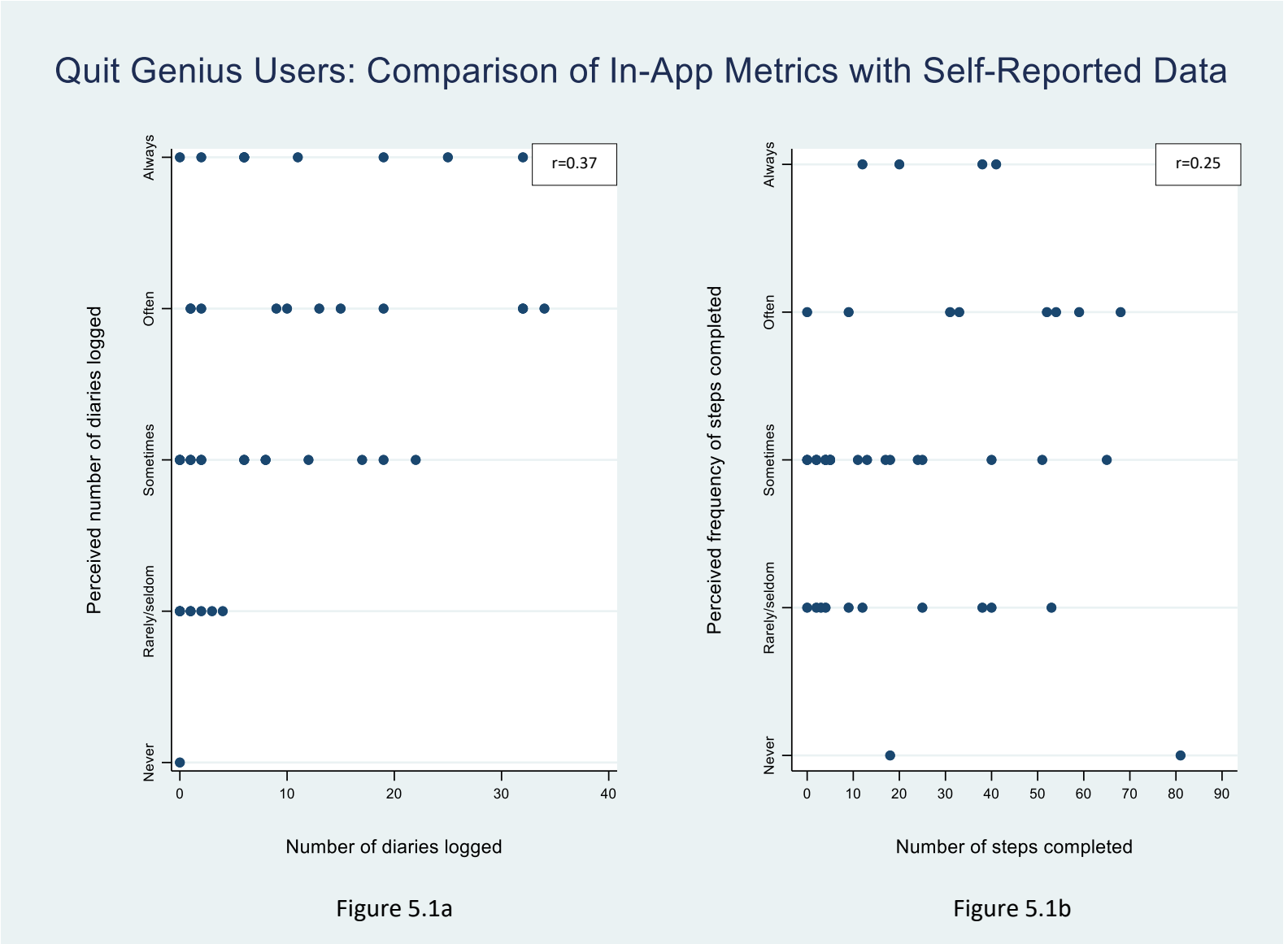


Figure 5.1a

Figure 5.1b

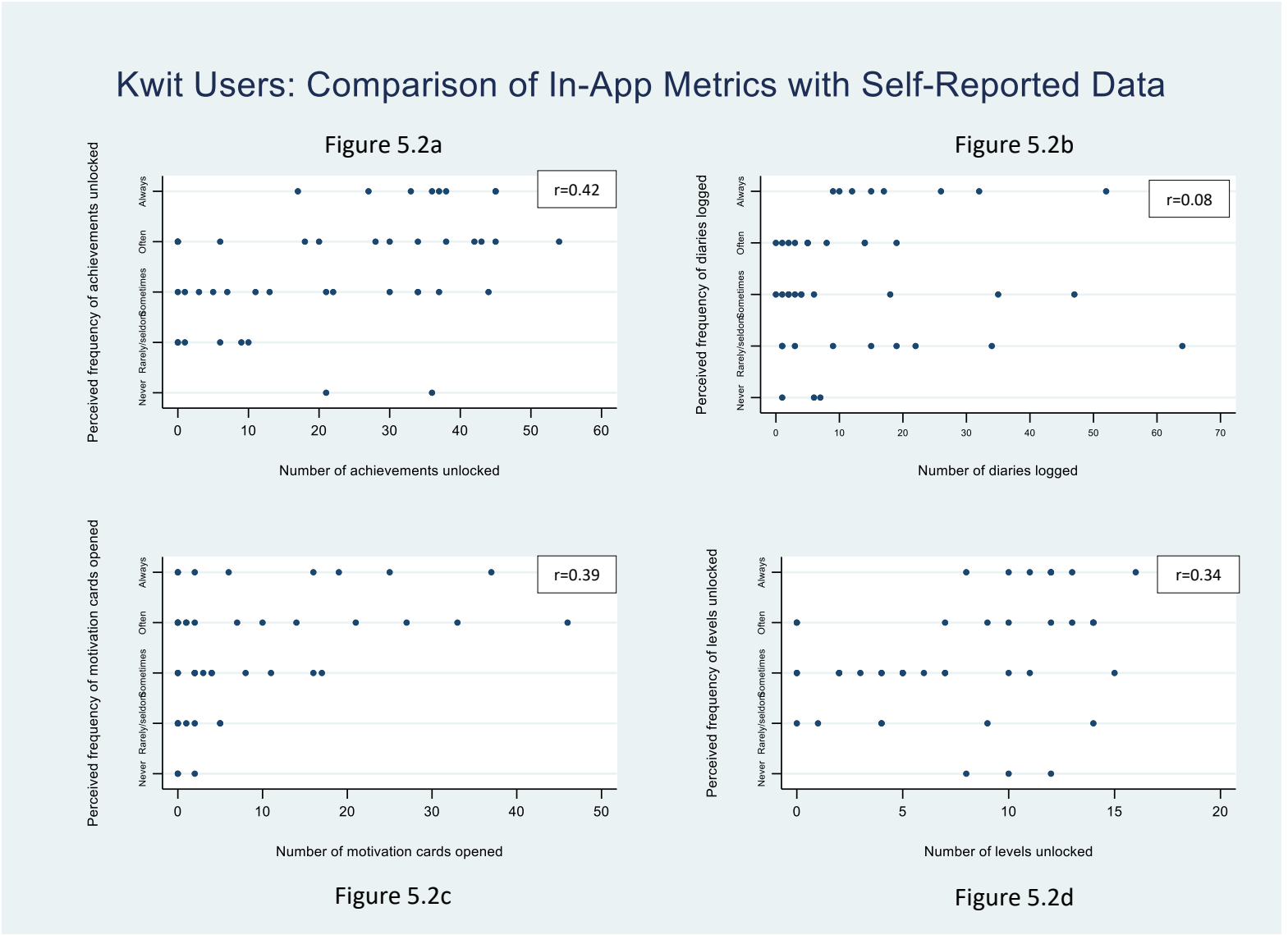
Kwit

Figure 5.2 displays the comparison between self-reported perceived frequency of use of some of the gamification features in the Kwit app and engagement with those features based on in-app metrics. The scatter plot in figure 5.2a shows the self-reported frequency of unlocking achievements (x-axis) against the number of achievements unlocked by app users according to in-app metrics (y-axis). A positive trend where app users that indicated they "often" or "always" unlocked achievements on the app also unlocked a higher number of achievements according to in-app data was found. A Pearson correlation test revealed that there is a statistically significant moderate correlation between self-reported and in-app achievements unlocked (r=0.42, p-value=.004). The scatter plot in figure 5.2b shows no visible trend between self-reported frequency of logging smoking diaries and the number of smoking diaries logged according to in-app metrics; this was confirmed with a Pearson corelation test (r=0.08, p-value=.597).

Figure 5.2c shows that a positive trend between self-reported and in-app data on the number of motivation cards opened is visible. A Pearson correlation test found that there is a statistically significant moderate correlation between the perceived and actual frequency of use (r=0.39, p-value=.009). Similarly, the scatter plot in figure 5.2d shows a comparison between self-reported frequency engagement with the levels feature (x-axis) and in-app data indicating how many levels were unlocked by app users (y-axis). A positive and moderate statistically significant correlation between in-app and self-reported data was found with regards to the levels feature (r=0.34, p-value=.022).

Despite the general moderate correlations found between in-app and self-reported data, some discrepancies can be seen. For example, for all the features presented in figure 5.2, there are some app users that claim to "never" have used the feature but in-app data shows that they did engage with feature. This is particularly the case for number of diaries logged and number of levels unlocked. On other hand, there are some app users that claim to "always" have used a certain feature but in-app data shows that the feature was engaged with infrequently. This is particularly the case for number of diaries logged and number of motivation cards opened.

Figure 5.2 Comparison of in-app metrics with self-reported data for Kwit users



5.5 Discussion

5.5.1 Overview of Findings

The analysis of the in-app metrics resulted in some key findings. On average, Quit Genius users opened the app 43 times and Kwit users 31 times during the 4-week study period (objective I). Due to additional data from Quit Genius, it was found that participants engaged more with Quit Genius during the first half of the study period compared to the second half; the same could not be examined for Kwit due to lack of data. The analyses presented in this chapter indicated that engagement with some of the features of the mobile apps were associated with an increase in change in self-efficacy between baseline and end-study (objective II). For Quit Genius users, this included engagement with the steps/levels feature. Although not significant when adjusting for other variables, engagement with motivation cards, steps/levels and achievements was associated with change in self-efficacy for Kwit users. However, no association was found between engagement with the features (determined via in-app metrics) included in the analyses and change in motivation to quit for both Quit Genius and Kwit users. Similar to change in self-efficacy, some factors were found to be associated with 7-day self-reported smoking cessation (objective III). For Quit Genius users, the amount of time spent on the mobile app, and for Kwit users, achievements unlocked and levels completed were associated with increased odds of reporting cessation. Another component of the analyses presented in this chapter was the comparison of self-reported data with in-app data (objective IV). Some trends with weak to moderate correlations were found between self-reported perceived frequency of engagement with app features and engagement with app features based on in-app metrics.

5.5.2 Gamification, Self-Efficacy and Motivation to Quit

The higher level of engagement with Quit Genius during the first half of the study compared to the second half is consistent with an earlier finding described in chapter four, which showed that the majority of change in self-efficacy occurred during the first 2 weeks of the study. This could imply that the higher engagement with the app during the first 2 weeks of the study played a role in participants having higher levels of self-efficacy during the same time, suggesting that app engagement could have led to higher self-efficacy. This would be in line with some past studies that have investigated the impact of app engagement on self-efficacy and health outcomes. For example, a systematic review by Spaulding et al. (2021) suggested

that higher engagement with mobile apps for prevention and management of cardiovascular disease was associated with better outcomes, such as lower body weight and body mass index[199]. Similarly, Hood et al. (2020) found that higher engagement with a mobile app for sickle cell disease management was associated with higher self-efficacy levels among young adults and adolescents[200]. However, it could also be that increase in self-efficacy and app engagement were coincidentally at the same time or driven by other factors. For example, it could be that higher engagement and self-efficacy during the first 2 weeks of the study are driven by a novelty effect of the app. Koivisto & Hamari (2014) found that users that engaged with a digital gamified intervention for physical activity experienced novelty effects where engagement levels and perceived usefulness of the intervention declined with more use[201]. Unfortunately, no inferences about engagement levels at different study timepoints for Kwit users could be made due to lack of data.

The analyses presented in this chapter also found that the steps/levels feature for Quit Genius and Kwit users (in the unadjusted model) was statistically significantly associated with increase in self-efficacy between baseline and end-study. Steps/levels is one of the only features for which engagement also determined by self-report was found to be associated with change in self-efficacy between baseline and end-study. This provides further confidence in our finding that steps/levels play a role in influencing self-efficacy. Even though analyses from the in-app data are exploratory in nature, the findings shed light on the possible importance of having incremental steps or levels in a smoking cessation intervention. App users can only access or advance to the next stage or level after completion of the last, and therefore, it could be that this feature helps app users keep track of their progress and provides them with feedback. According to some studies, having different levels or steps functions a form of goal-setting and can "mark progression of difficulty and thus increase self-efficacy"[202-203].

Aside from levels/steps, the analyses suggest that the number of achievements unlocked on the Kwit app was associated with an increase in self-efficacy between baseline and end-study. Achievements unlocked, similar to awarding badges, are presented to app users when they have reached certain milestones in their quit journey related to health, money, well-being and various other aspects. Some examples of achievements presented to Kwit users include saving

50 Euros, not smoking 20 cigarettes, 2 weeks as a non-smoker and elimination of carbon monoxide from body. Similar to research on levels/stages, the integration of achievements could be associated with increased self-efficacy levels because gamification elements such as achievements and badges may function as goal-setting devices. According to Gnauk et al. (2012), achievements signal progression to app users as they receive rewards for attaining concrete goals[203]. Some other theories suggest that by reminding and providing app users with evidence of past achievements and successes via badges, app users experience higher levels of competence which in turn could influence one's confidence in their ability to refrain from smoking[202]. The positive effect of providing regular feedback in all types of smoking cessation interventions, face-to-face or remote, is generally well-established in the literature[204].

On the other hand, none of the in-app metrics which assessed engagement with gamification elements for both Quit Genius and Kwit were found to be associated with change in motivation to quit. Apart from the steps/levels feature, similar models run with self-reported data in chapter four also found that engagement with app features was not associated with change in motivation to quit. A possible explanation could be that features that were not assessed in the study were responsible for change in motivation to quit. For example, it could be that the quit coach function in Quit Genius which provides app users with personalised support throughout their quit journey or the distraction exercises to help smokers resist cravings are features that helped increase motivation to quit. It is also possible that since motivation is a highly intrinsic and personal construct, it is more difficult to influence or change compared to self-efficacy. Alternatively, gamification elements may not have facilitated increases in motivation as some of the elements may not have been perceived as informational. According to Mekler et al (2013), feedback and rewards provided by gamification elements that are perceived to be controlling rather than informational could undermine efforts to influence intrinsic motivation by reducing feelings of autonomy, an important component for motivation according to the self-determination theory, a prominent theory of motivation[205]. It could also be that most of the participants were already motivated "enough" since they decided to participate in the study, which could mean that there was not much room for additional increases in motivation. The lack of significant associations could also be a result of imperfect measurement of both motivation to quit and engagement based on in-app metrics.

Furthermore, having higher baseline motivation was associated with a smaller improvement in motivation to quit and having higher baseline self-efficacy was associated with a smaller change in self-efficacy after 4 weeks of using the app among both Quit Genius and Kwit users. This is consistent with similar regression models run in chapter four with self-reported data instead of in-app metrics. This suggests that both perceived and actual use of gamification features in the app are associated with a greater benefit for individuals with lower levels of confidence in their ability to quit smoking and individuals that place a lower level of importance and determination on their quit attempt. With regards to age and gender, the analyses show that both change in self-efficacy and motivation to quit was consistent regardless of age and gender. This is an encouraging finding as it implies that the impact of the apps is not limited to a particular age group or gender. However, it is important to note that the majority of participants in the study were male and belonging to a younger age group. Moreover, participants interested and enrolled in the study are likely to already be motivated to quit smoking from the beginning, which is something that needs to be taken into account when interpreting the findings of the study.

5.5.3 Gamification and Smoking Cessation

Aside from self-efficacy and motivation to quit, the association between app engagement based on in-app metrics and 7-day self-reported smoking cessation was also explored. For Quit Genius app users, the amount of time spent on the app was associated with greater likelihood of reporting successful 7-day cessation. Although the small sample size should be considered when interpreting this result, this finding is in line with a systematic review which found that app engagement (e.g. number of app openings, time spent on the app, interaction with features etc.) was associated with a statistically significant increase in quitting rates[137]. In terms of specific features, due to limited in-app data, only diary logging and step completion were included in the exploratory regression model for Quit Genius. Interestingly, diary logging was associated with a lower likelihood of reporting successful cessation. It could be that Quit Genius users logged smoking diaries when they were more likely to experience relapses. For example, since smoking diaries are often used to log cravings, craving intensities and triggers, it could be that individuals logging more diaries are experiencing greater difficulty with their quit attempts. Unfortunately, specific data on what users logged in the diaries was not shared and therefore this speculation could not be validated.

For Kwit users, engagement with some features, such as unlocking achievements, was found to be associated with increased odds of reporting successful 7-day cessation at the end of the study. The association between unlocking achievements and both higher change in self-efficacy and successfully quitting provides stronger evidence for the role of features such as achievements or badges in supporting behaviour change. It could be that the achievements remind app users of their success, which positively influences their confidence in their ability to quit, and in-turn their likelihood of quitting[97]. However, it is also important to note that obtaining achievements inherently implies that app is rewarding users for staying quit. Although difficult, future studies could attempt to include duration of engagement with such features (e.g. amount of time spent on achievements screen rather than number of achievements unlocked) in order to understand the relationship more clearly between engagement with such features and smoking cessation. Finally, unlike with Quit Genius, the odds of 7-day smoking cessation are found to be consistent regardless of age and gender. This suggests that the likelihood of successfully quitting was equal among app users of different ages, and between males and females after adjusting for other usage metrics. A possible resulting implication is that Kwit may be a more suitable option for older aged smokers, who are likely to be more nicotine dependent. However, further research would be required to test the impact of the apps on different age groups with a larger and more diverse sample.

5.5.4 Comparing In-App and Self-Reported Data

Generally, self-reported and in-app data for frequency of use of features among Quit Genius and Kwit users were positively moderately correlated. This is consistent with findings from several studies in the field of media communication that have explored differences between self-reported (i.e. perceived use) and log data (i.e. actual use) in mobile phone use. For example, Boase & Ling (2013) found that self-report data correlated positively and moderately with server log data on frequency of mobile phone use[194]. Similarly, a systematic review of discrepancies between logged and self-reported digital media use also found that self-reported use moderately correlated with logged measurements[206]. Whilst many studies report moderate correlations between the two types of data, they also find that self-report does not always accurately reflect actual mobile phone use, with some claiming that self-report overestimates actual use[193,207], and others claiming that it underestimates it[197]. Although there is some agreement between the findings of the analysis presented in this

chapter and other studies, the majority of studies that investigated differences between the two types of data focus on general mobile phone use (e.g. amount of time spent on a mobile phone, number of phone calls, duration of phone calls etc.) rather than engagement with apps, let alone specific app features.

Despite the moderate correlations between self-reported and in-app data for Quit Genius and Kwit users, there are some obvious discrepancies for a few users between the two types of data where self-reported use mismatched with actual use. For example, some Kwit users self-reported that they "never" used the diary feature but in-app data indicated otherwise. A possible reason for this could be because the users may not have understood what was meant by "logging a diary". This would strongly suggest the need for future studies to test and validate the assessment of self-reported frequency of use. Future research could also include qualitative interviews to gain an understanding of whether app users understood exactly which feature is being referred to in self-report questionnaires.

However, it is important to note that the comparison between self-reported and in-app data is particularly difficult to interpret for the diary feature in the Kwit app because of some changes that the app had made whilst the study was still running (e.g. the term "diary" was replaced with a plus symbol). These types of issues were difficult to predict and adjust for during the study period and are known difficulties for research conducted in a field that constantly and quickly changes. Aside from issues related to the self-reported data, discrepancies could also have resulted from limitations of the in-app metrics which are discussed subsequently (section 5.5.5). Some of the discrepancies where participants report that they "always" use a certain feature but in-app metrics indicates otherwise, could be due to self-report bias. It may be that participants were not able to accurately recall how often they used the mobile apps and/or were responding to questions in a manner that they believe would be viewed more favourably by others. Studies have shown that participants can have difficulty accurately recalling behaviours due to cognitive limitations, and as a result, self-reported responses can often reflects perceptions of behaviour rather than actual behaviour[194,206].

Even though there can be discrepancies between the two types of data, there is merit in using both in order to understand engagement. Perceived frequency of use based on self-report provides additional contextual information that is not provided by data on actual use. For example, self-report captures frequency of use based on what was memorable for the user. This could have implications for which features required a greater amount of cognitive resources from the user, as it may be that features that require a lower amount of cognitive processing from the user are also less accurately recalled[198]. Similarly, features that bring more enjoyment to the user whilst being used could alter memory of use and individual perception of passage of time[198]. Comparing self-reported and in-app data can also provide information regarding varying needs of support; using the app once a week may be considered "often" to some users but "rarely" to others. Both types of data provide different but complementary information which can lead to varied findings, particularly when investigating their association with cognitive factors such as self-efficacy and motivation to quit[208]. Consequently, when feasible, employing both types of data, should be considered in future studies.

5.5.5 Strengths, Limitations and Future Research

Although some general findings can be deduced from the analyses of in-app metrics, it is important that these findings are interpreted with caution. One of the reasons for this is the limitations and challenges associated with the collection, analysis and interpretation of the in-app data. During the design and development of the study, it was expected that several other in-app metrics would be collected and shared in order to better understand engagement levels, specifically with gamification features that were also assessed using self-report. For example, time spent on the badges screen or the progress dashboard were metrics that were initially meant to be collected. However, due to technical constraints that arose during the data collection period, many of the originally planned metrics were not collected. As a result of the lower than expected quantity of in-app data, exploring the association between engagement with certain gamification features based on in-app data and key study outcomes was not possible; it was also not possible to make comparisons between self-reported and in-app data on engagement for some of the gamification features.

Aside from the quantity of in-app data, some weaknesses with regards to the quality of the data were also identified. During the study, apps were occasionally updated (i.e. update to fix minor bugs, removal of a certain motivation card etc.). App developers mentioned that this could have affected collection of some in-app metrics and perhaps caused technical errors. Some of these errors were found by the identification of discrepancies between collected in-app metrics. For example, the metric for the number of times the app was opened may not have been able to capture every time a user opened the app if it considered the app to be already open (in the background of a user's mobile phone). There were also a few cases where it showed that the user did not open the app at all or only once, despite other metrics indicating time spent on the app or engagement with some app features. App developers also mentioned that data capture of some features was limited by differences in background processing of apps in the underlying technical systems (i.e. iOS compared to Android versions of the apps). Such differences between operating systems and the mobile apps could have affected the reliability of the in-app metrics.

As a result of the limitations arising from the quantity and quality of in-app data, analyses were only able to be run for small sample sizes. Since both apps had different in-app metrics collected, separate analyses for each one had to be conducted. After excluding some participants for inadequate data (i.e. no minutes spent on app) and discrepancies within in-app metrics, data for 45 Quit Genius users 44 Kwit users remained. As a result of this, small sample sizes were used for the regression analyses, for which only a limited number of variables could be included. It would be valuable for future studies to obtain in-app metrics for a larger sample size in order to more robustly investigate the use and impact of mobile app features.

Finally, there are also some methodological limitations of the study itself. As discussed in chapter four, a majority of the participants of the study were found to have low-moderate dependence on nicotine. This could mean that the findings may not be applicable to participants which a high level of dependence on nicotine. Similarly, individuals with mental health conditions were excluded from participating and it may be that the findings are not generalisable to individuals with mental health conditions. In light of the constraints and limitations discussed, it is important to note that the presented analyses involving in-app

metrics are of exploratory nature and for hypothesis-generating rather than hypothesis-testing. Future research could try to address these drawbacks by having a larger and more diverse sample to improve reliability and generalisability of the findings. Moreover, researchers interested in including in-app metrics in their studies would need to focus on timely data collection to avoid factors outside of their control (such as new versions of apps being released) affecting the scientific validity of the findings.

5.6 Chapter Summary

This chapter presents the findings from an exploratory analysis using in-app metrics to better understand the association between gamification and cognitive factors vital for quitting such as self-efficacy and motivation to quit. Some game elements, such as the steps/levels feature, were associated with change in self-efficacy between baseline and end-study, and smoking cessation. Additionally, comparisons between in-app and self-reported data found that they were generally correlated but not particularly strongly. Comparing in-app and self-reported data provides additional contextual information such as the amount of cognitive processing exerted by the user or the level of support a user needs during a quit attempt. The small sample size along with the limitations of the data should be considered when interpreting the findings presented. Future studies could try to use a larger and more diverse sample, along with more rigorous measures of engagement via in-app metrics.

Chapter Six: Overarching Discussion

6.1 Overview of Research Objectives

The overall goal of my research was to investigate the role of gamification in mobile apps for smoking cessation. As presented in chapter one, the primary objectives of the thesis were to I) explore the use of gamification in smoking cessation mobile apps, II) examine the effects of gamification in mobile apps for smoking cessation on self-efficacy and motivation to quit and III) compare self-reported and in-app data on engagement with gamification elements. The secondary objectives of the research were to IV) investigate adherence of smoking cessation mobile apps to evidence-based guidelines and V) explore the impact of gamification on smoking cessation outcomes. These objectives were addressed by three core components of the research presented in this thesis.

6.2 Summary of Methods and Key Findings

The first component of the thesis was the mobile app review (chapter three) where I systematically examined smoking cessation mobile apps available on the UK Android and iOS app market in 2018. The review assessed incorporation of gamification strategies and tactics in smoking cessation apps (objective I) and app adherence to evidence-based treatment guidelines (objective IV). The review found that a majority of the apps had low adherence to UK-specific and international smoking cessation guidelines. This finding is consistent with other mobile app reviews for different app markets[148-151]. In terms of gamification, the majority of apps adopted at least one gamification strategy or tactic and only a small proportion of apps incorporated a high level of gamification. Although other mobile app reviews have also reported widespread use of gamification[116], one review found that only a few health apps integrated gamification[22]. This inconsistency is likely due to the different methods adopted to identify gamification. In my review, some of the common gamification strategies/tactics incorporated into smoking cessation mobile apps were showing progress and providing feedback; such strategies are also often inherently present in mobile apps and therefore could have led to a higher level of detected gamification. On the other hand, some of the less common features in smoking cessation apps included showing game leaders and having a story/theme.

Following from the mobile app review, I conducted a 4-week online study called the *Stop Smoking Study*, which investigated the impact of gamified smoking cessation mobile apps on the self-efficacy and motivation to quit of smokers seeking to quit (objective II). The apps that I chose to include in the study were identified using the mobile app review of smoking cessation apps presented in chapter three. The analysis of the self-reported data collected during the study was the second component of my PhD thesis (chapter four) and led to some important findings. For example, participants experienced increased levels of self-efficacy and motivation to quit after 4 weeks of using the apps compared to baseline, and the largest proportion of this change took place during the first 2 weeks of the study. This finding is important and encouraging for smokers seeking to quit as self-efficacy and motivation to quit have been found to be associated with increased odds of successfully quitting[8-11,13-15].

Regarding gamification, self-reported frequency of use of overall gamification was associated with increased change in self-efficacy and motivation to quit. After examining the effects of specific game elements, the results showed that perceived frequency of engaging with the levels/steps feature was associated with both increased change in self-efficacy and motivation to quit. Additionally, having higher baseline self-efficacy was associated with a smaller change in self-efficacy, and having higher baseline motivation to quit and education were associated with smaller changes in motivation to quit between baseline and end-study. This suggests that the apps had a greater impact on individuals with lower self-efficacy and motivation to quit as those individuals had more room for improvement. Although not a primary outcome of my research, I also analysed the effects of gamification on smoking cessation (objective V). Out of the 116 participants that completed the study, 23% reported successful 7-day cessation at the end of the study; this is within the range of what was found in other mobile app studies in the literature[137]. Further discussion on quitting rates after app engagement and how these compare to other smoking cessation methods is discussed in the subsequent section on implications of the findings. Similar to self-efficacy and motivation to quit, self-reported frequency of engagement with the levels/steps feature was also associated with 7-day smoking cessation.

The third component of my thesis was an exploratory analysis with in-app metrics (chapter five). My collaboration with the app developers of Quit Genius and Kwit during the

development and execution of the *Stop Smoking Study* was an integral part of this component. Although Kwit developers shared aggregate 4-week data and Quit Genius developers shared data for multiple study timepoints, the overall amount and quality of the in-app data was lower than expected. Despite this, the analyses of in-app metrics resulted in some key findings. For example, Quit Genius was used more by participants during the first 2 weeks compared to the last 2 weeks of the study. Interestingly, both the increased level of engagement with Quit Genius and the higher proportion of change observed in self-efficacy and motivation to quit levels occurred during the first 2 weeks of the study. Similar to self-reported data, engagement with the levels/steps feature based on in-app data, was associated with an increase in change in self-efficacy after 4 weeks of app use compared to baseline for both Quit Genius and Kwit users. Unlike the results of analyses with self-reported data, there was no association found between frequency of use of the features based on in-app metrics and change in motivation to quit.

In terms of smoking cessation, for Kwit users engagement with the achievements/badges feature was associated with successful 7-day cessation and for Quit Genius users time spent on the app was associated with a higher likelihood of quitting. The exploratory analyses in chapter five also compared perceived frequency of use of gamification features (self-report) with actual frequency of use (in-app metrics) and generally found moderate positive correlations between the two types of data (objective III). This finding is in line with other studies that have compared self-reported data with log usage data[194,206]. Despite the moderate correlations, there were some discrepancies between the two types of data, which highlighted the importance and usefulness of including both in academic research.

Overall, the learnings from the three components of my research highlight that gamification can play a role in facilitating self-efficacy and motivation to quit among smokers seeking to quit. However, further research is necessary to better understand how and why this is the case, and whether the findings are applicable to other population groups. The analysis of both self-reported and in-app data allowed for a better understanding of which gamification features that users engaged with could be incorporated into future mobile apps. The following section of this chapter discusses the implications of the main findings and highlights some key

recommendations. The discussion also describes some of the challenges I faced during my PhD, the limitations of my research and how these could be addressed by future studies.

6.3 Implications of Findings

The main findings of this thesis have many important and practical implications. They can help inform the development and design of smoking cessation mobile apps, provide critical insights for health behaviour change and highlight some key recommendations for tobacco control and public health policy.

6.3.1 Gamification and Behaviour Change

The findings of my thesis have important implications for behaviour change. One of the key learnings of my thesis was the positive effect of frequency of engagement with gamification on important success factors for quitting smoking such as self-efficacy and motivation. The literature shows that having high self-efficacy is rigorously associated with quitting smoking and maintaining cessation in the long-term[8-11]. Similarly, high motivation to quit levels have also been found to increase the odds of making a quit attempt and successfully quitting[13-17]. Aside from being central components for the quitting process, self-efficacy and motivation are also important factors for driving change in relation to other behaviours such as increasing physical activity levels and improving dietary habits[86-87]. Due to the crucial impact of these cognitive factors on a range of health behaviours, the positive effects of gamification can have far reaching implications for the role and application of gamification in designing and implementing both remote and in-person behaviour change interventions.

Moreover, since gamification shares key elements with behaviour change techniques, an enhanced understanding of behaviour change theory could better explain the underlying processes at play when gamification is applied to mobile app interventions[21,210-211]. This understanding could also help inform which gamification elements align best with which behaviour change therapies. For example, since both the apps used in my research were based on cognitive behavioural principles, it could be that the effects of the gamification elements were only present because they worked well in combination with the integrated behaviour change techniques in the apps. However, the same effects or influences of gamification may not be present in apps based on other therapies, such as apps based on action and commitment therapy[26].

Similarly, the choice of gamification elements can be influenced by the underlying psychological theory that a mobile app leverages to elicit behaviour change. For example, an mHealth intervention that focuses on the self-determination theory would attempt to fulfil the need for competence, autonomy and social relatedness to motivate individuals to engage in a specific behaviour. In that case, some game elements would be better suited to enhance competence (e.g., performance feedback, rewards/badges), boost autonomy (e.g., goal setting), and foster social relatedness (e.g., leaderboards, social community, sharing) compared to other elements[212-213]. Due to the overlap between gamification principles and behaviour change strategies, the input of behaviour change specialists in gamified smoking cessation interventions, remote or face-to-face, would be essential to maximise intervention effectiveness.

6.3.2 Tobacco Control Policy

One of the key findings of my research was the 10% continuous 4-week abstinence rate and the 23% 7-day point prevalence of abstinence rate reported after using the apps for 4 weeks. These quitting rates are generally within the range of those reported by other mobile app studies[137]. For example, a systematic review found that quitting rates ranged between 13 to 24% across RCTs assessing the impact of mobile app interventions[137]. Mobile app interventions based on other behavioural change theories such as mindfulness and action commitment therapy rather than cognitive behavioural therapy, also reported comparable 4-week cessation rates[138-140]. However, the quitting rates of the gamified apps in this study, and mobile app-based interventions in general, are lower compared to other evidence-based smoking cessation methods. Research shows that the 4-week quitting rate for individuals who access English stop smoking services is approximately 36% and the 1-year quit rate is approximately 8%[4]. These figures are based on studies where smokers accessed cessation services and received behavioural counselling and/or NRT support. The 1-year quitting rates were highest among individuals that received group specialist support (12.1%) followed by one-to-one-support (10.2%), whilst receiving support from a general practitioner or pharmacy service had a lower quit rate of 5.1%[4]. Another study found that receiving aid from a stop smoking advisor and using a stop smoking aid (such as NRT products) was associated with a 1-year quitting rate of 16%[60].

Additionally, one RCT found that the 7-day point prevalence of abstinence reported 4 weeks post quit date was higher among users that engaged with a mobile app intervention (44.5%) compared to very brief advice which is recommended by the UK's smoking cessation guidelines (28.7%)[195]. Although the quitting rate found by the RCT is higher in comparison to what was found by the studies discussed in this thesis, direct comparisons of the efficacy of interventions should be made with caution due to varied methods of measuring cessation (e.g. point prevalence, continuous abstinence etc.) and different durations of the intervention period. Regardless, compared to no assistance or quitting with will-power alone, the mobile app interventions investigated in this thesis seem to be more beneficial[60].

My research also found that two gamified mobile apps for smoking cessation had positive effects on important cognitive factors associated with successfully quitting. This implies that smokers seeking to quit but are not willing or able to access face-to-face cessation services, could consider using mobile apps, such as Quit Genius and Kwit, to support their quit attempts as they can provide personalised, real-time and persistent support. Due to the wide-reach and low cost of mobile apps, this finding could have important implications for the development and dissemination of mHealth as a cost-effective channel of alleviating the burden of the tobacco epidemic.

It would be beneficial for tobacco control policymakers to consider implementing methods of actively promoting apps that adhere to evidence-based guidelines and incorporate strategies, such as gamification, which can positively influence critical success factors for quitting. The findings of my PhD research showed that features such as levels/steps, were features that users frequently interacted with (based on in-app metrics), remembered their interaction with (based on self-report) and were associated with higher self-efficacy and motivation to quit. Based on these findings, it may be beneficial to promote apps that include such gamification elements. This would help ensure that apps that are most likely to bring health benefits are available to smokers seeking to quit. One way to achieve this would be to have funding streams that encourage collaboration between mobile app developers, behaviour change specialists and gaming experts. This could facilitate the development and/or endorsement of apps that adhere to public health recommendations and benefit from the expertise of a wide variety of specialists to maximise effectiveness. Additionally, funding for the endorsement,

advertising and regular updates of apps would be useful in ensuring that the most effective apps remain on the market.

Moreover, my research also showed that individuals with a lower level of education, which can be a proxy for socioeconomic status, were likely to experience a greater benefit from the gamified smoking cessation apps than individuals with a higher level of education. Other studies in the literature have also found that mHealth can positively impact individuals of lower socioeconomic status[39]. Based on this, public health policymakers could focus on promoting and ensuring such interventions are readily available to those that could benefit the most from them. This could help attenuate health disparities in relation to smoking prevalence and smoking cessation. Since the number of smokers seeking face-to-face support has been falling over the past few years in the UK[5-6], tobacco control and public health policymakers could consider prioritising the development and dissemination of effective smoking cessation mobile apps. However, the role and fit of gamified smoking cessation mobile apps with other smoking cessation services and interventions needs to be more carefully examined. It could be that gamified mHealth solutions would work best as additional or supplementary to conventional smoking cessation support for some types of smokers (e.g. smokers that can seek face-to-face assistance) but as the primary form of support for other types of smokers (e.g. smokers that are not able or willing to use in-person services). Further information on this would help ensure that the role of gamified smoking cessation apps for different types of smokers is considered in the development and implementation of smoking cessation treatment guidelines.

6.3.3 Mobile App Design and Development

The findings of my research provide practical implications and suggestions that can support the design and development of mobile app interventions. According to the mobile app review presented in chapter three, a majority of smoking cessation apps do not adhere to evidence-based guidelines. As a result, there are likely to be many apps on the market that are not very effective in helping smokers quit[155]. In order to make sure that those seeking assistance via mHealth solutions have the best chance of quitting, access to evidence-based apps that are able to keep users engaged would be beneficial. If the markets are flooded with mobile apps that do not include scientifically validated content, smokers are less likely to successfully

change their behaviour. Failed quit attempts due to the use of low quality mobile apps could negatively impact a smoker's confidence in making or continuing a quit attempt. In turn, this could hinder the pursuit of more effective mobile apps or other smoking cessation interventions in the future. Consequently, it is vital that good quality apps that have been scientifically vetted and validated are accessible to smokers trying to quit. To ensure availability of such apps, mobile app developers would need to consider investing in research during the app development phase to demonstrate compliance with evidence-based guidelines. This could help ensure that apps follow treatment guidelines and incorporate relevant strategies to maximise intervention effectiveness.

The *Stop Smoking Study* particularly demonstrated the likely effectiveness of the steps/levels game element as it was associated with change in self-efficacy when considering both perceived and actual frequency of use. It was also found to be associated with successful smoking cessation. Despite the results of my study highlighting the effectiveness of the steps/levels feature, the mobile app review presented in chapter three showed that only 20% of smoking cessation apps on the UK market included this feature. Given its effectiveness, incorporating this feature into mobile app interventions for smoking cessation may enhance self-efficacy levels of smokers and improve the likelihood of quitting.

On the other hand, according to the results of the *Stop Smoking Study*, participants perceived the sharing feature to be the least useful. It was also a feature that was seldomly used by participants according to both self-reported and in app data, and was not associated with change in self-efficacy or motivation to quit. According to the mobile app review, almost half of the apps on the market include a social connectivity feature. However, similar to Quit Genius and Kwit, the majority of apps reviewed only incorporated a share button which users can click on to share certain achievements or milestones with others using social media or text messaging. Several studies in the literature show that having a social connectivity feature can have a positive influence on cognitive factors associated with quitting. However, the studies indicate that having a complex social/sharing feature is more effective[209]. For example, creating a community of users within an app could facilitate social interaction and feelings of relatedness[209], which in turn could positively impact both self-efficacy and motivation to quit. Therefore, in order to foster user engagement and overall efficacy, I would recommend app

developers to consider building a community of users for their app, even if it is more difficult and time-consuming to do so compared to a simple share via social media feature.

Unlike the share feature, participants perceived showing progress as one of the most useful features. According to the mobile app review, showing progress was also found to be the most common feature incorporated into mobile apps. Despite this, perceived engagement with the feature (based on self-reported and in-app data) was not associated with an increase in change self-efficacy or motivation to quit. This could be due to imperfect measurement of engagement resulting from participants experiencing difficulty in judging frequency of their interaction with a feature that is inherently present and often quickly glanced at by users. Alternatively, since the steps/levels feature is a form of progress tracking and was found to influence self-efficacy and motivation to quit, it could be that the way in which an app manifests progress tracking (e.g. levels/steps, points or badges/achievements) is more impactful. However, since progress tracking was perceived to be a useful feature, app developers could continue including general tracking features such as progress dashboards (e.g. a page on the app that shows key quitting metrics such as days quit, money saved, other benefits accrued etc.). At the same time, it may be beneficial for app developers to incorporate more complex progress tracking via features such as levels/steps as engagement with them was associated with better self-efficacy, motivation to quit and quitting success.

Finally, my research showed that the amount of time spent on gamified apps (specifically referring to Quit Genius) was associated with an increased likelihood of quitting. Therefore, a key goal of app developers is to design and develop apps that can lead to a high level of engagement from users. This would ensure that apps are used more often and for a longer duration, which can help retain users. It is likely that frequency of use of gamification was associated with higher change in self-efficacy and motivation to quit as a result of increased interaction/engagement with the app. Past studies have also found that gamification can improve app engagement[190,145], and in doing so, could encourage long-term use of the app and facilitate smoking cessation. Apps that demonstrate effectiveness and high engagement would be preferred by end users and likely have a greater number of downloads.

6.4 Assessment of Biases and Measures, Limitations and Future Research

Although my thesis provides a good starting point for further research and effectively builds on the current knowledge of the role of gamification in mobile apps for smoking cessation, there are challenges that I experienced during the research process, and limitations and unanswered questions that need to be addressed. In the following section, I provide a brief assessment of the potential biases that may have influenced the research which has been presented, a summary of the strengths and limitations of the tools and measured used, and a general discussion of some of the limitations of the research.

6.4.1 Assessment of Potential Biases

The studies presented in this thesis have been affected by some biases. For example, it is possible that the collected self-report data included in the analyses presented in chapters 4 and 5 was subject to recall bias. For example, it may have been that participants who successfully quit smoking after using the app or found the app to be useful could recall their engagement better than those who did not quit. This could mean that quitters may have reported a higher level of engagement with the app compared to non-quitters, even if both types of participants have spent the same amount of time on the app. Additionally, general issues of inaccurate or difficulty self-reporting engagement could also have played a role. Some studies show that due to cognitive limitations, accurate recall can be difficult with responses reflecting perceptions of behaviour rather than actual behaviour itself[194,206].

It could also be that the self-reported data was subject to social desirability bias, where participants responded to questions in ways that they believed would be more favourably viewed by others. This could have been the case when reporting frequency of engagement with the mobile apps but also for self-report of smoking status. Research shows that participants can report successfully quitting smoking in order to be viewed more favourably by others[194]. Aside from biases associated with self-report, selection bias is another type of bias that should be acknowledged. As mentioned in chapter 4, since a majority of the participants were male, highly educated and had low to moderate dependence on nicotine, it is likely that the findings of the studies are not generalisable or representative for all smokers seeking to quit. The findings could also be subject to healthy volunteer bias as the participants self-selected themselves to take part in the study and are therefore likely to have a higher

level of baseline motivation compared to smokers seeking to quit that did not volunteer to participate in the study.

6.4.2 Assessment of Measures and Tools

A discussion regarding the measures and tools used in the studies presented in this thesis is also warranted as some of the limitations could be addressed by future studies. Self-efficacy was measured using the SEQ-12 tool which has been found to have high construct, content and predictive validity[88]. It is also a tool that has demonstrated high test-retest reliability and internal consistency, been frequently adopted by other smoking cessation studies and translated for use in many other languages[94-96]. On the other hand, the tool used to measure motivation to quit is a two-item measure which has been adopted by the NCSCT and other smoking-related studies but it has not been as extensively validated as the SEQ-12[102-104]. It could be beneficial for future research to use other measures for motivation such as the readiness to change ruler which assesses an individual's motivational state for changing their behaviour or the Mondor motivational scale which is more comprehensive[101]. Although this is only a one-item measure, it is more broadly used in behaviour change studies and could allow for easier benchmarking against other research studies.

In terms of gamification, there is no existing tool in the literature that has been used to assess engagement with gamification features. Consequently, to fulfil the objectives of this thesis, a questionnaire was developed based on a review of the existing literature and the technology acceptance model[181]. Whilst this has been discussed in chapter 4, it is important to acknowledge that testing and validating the questionnaire would increase scientific rigor and allow for future research to adopt a standardised approach for assessing engagement with gamification. Finally, smoking cessation in the studies presented in the thesis was measured using self-report. Although research shows that using biochemical verification would improve the robustness of the findings and mitigate the effects of potential biases, biochemical verification is not generally recommended for low-intensity smoking cessation interventions such as those delivered via mHealth[195.]

6.4.3 General Limitations

Apart from potential biases and possible limitations of the tools and measures that were utilised, it is also important to discuss some of the overarching limitations of the research

presented in this thesis. Firstly, the mobile apps that were chosen for the main study presented in this thesis were apps that utilised cognitive and behavioural therapy principles. It could be that the focus on apps that follow guidelines and include theory driven content meant that the findings and implications of the research do not apply to other types of apps. Therefore, it would be interesting for future research to decouple adherence to guidelines or inclusion of scientific content with gamification. It could be that apps with gamification elements that do not include scientifically validated content or follow suggested treatment advice have the same effect on self-efficacy, motivation to quit and smoking cessation; it could also be that that such apps do not influence important cognitive and health outcomes in the same way.

Additionally, due to the observational nature of the main study, causality could not be inferred. In order to have a more robust understanding of the role of gamification in mobile apps for smoking cessation, more rigorously designed studies, such as RCTs, would be ideal. For my PhD, I would have liked to run a RCT which compared two apps that were identical or at least as similar as possible in terms of content and visual appearance but differed only in the type and/or number of gamification elements incorporated. Due to logistic constraints, this was not a feasible option for me to pursue. Despite this, the findings of my research can help lay the groundwork for the design and implementation of a future RCT within this field. Future RCTs could help quantify the effectiveness of gamification within the context of smoking cessation and generally for health behaviour change by investigating its isolated impact rigorously. Since it may not necessarily be that incorporating more features is better or more effective, understanding which features, alone or in combination with others, have the greatest possible impact would be beneficial. However, in order to design and run such RCTs, there would need to be strong collaboration between app developers and researchers. Moreover, it could also be insightful for future research to qualitatively investigate why certain gamification features were used more often than others, and further explore the general user acceptability of smoking cessation mobile apps; this could achieved by running focus group discussions and conducting in-depth one-to-one interviews.

It is also important to note that my research had a short-term outlook on the effectiveness of mobile apps for smoking cessation. However, research has reported that relapses occur over

a longer period of time, and therefore the ability of the apps to ensure cessation maintenance cannot be determined[98,195,214]. Herd et al. (2008) found that the relapse rate for smokers after four weeks of abstinence was approximately 64% whilst the relapse rate after abstinence for at least 6 months was 22%[98]. Similarly, a meta-analysis showed that after a year of abstinence, the relapse rate among smokers seeking to quit was 10%[214]. Consequently, future research could consider having a longer follow-up in order to better understand the long-term impact of gamified mHealth interventions on success factors for smoking cessation and smoking cessation itself.

Finally, my research tried to mitigate the negative consequences of over reliance on self-reported data, particularly on engagement with the mobile apps, by collecting and analysing in-app data. Although I was able to include some analyses with in-app data, collaborating with partners that are primarily focused on commercial rather than research outcomes can be challenging. Aside from technical limitations, the natural reluctancy for commercial entities to share certain information can make it difficult to obtain data. Due to lower than expected quantity and quality of the in-app data that was shared with me, the desired level of confidence for some of my findings was not achieved. It would be advisable for future researchers to anticipate and prepare as much as possible for any technical limitations of in-app data and the challenges that may arise during the data collection process. One challenge that I experienced was dealing with version changes from the app developers; version changes could affect my data collection as some questions presented to participants about specific features of the app, if removed or changed, may not have been valid anymore. Often the aim of companies that develop apps is to iteratively improve their offer to consumers in short development cycles, which poses a direct conflict with research objectives and the process of controlling all variables that may hinder the reliability of findings. Therefore, aligning aims and interests with commercial partners can be challenging. I would recommend future researchers to have clear and honest communication when working together with commercial entities to ensure better alignment and smoother collaboration.

Aside from the inclusion of in-app data, future studies could consider biochemically verifying smoking cessation via measurement of carbon monoxide levels in order to further reduce the biases and lack of reliability that arise from self-reported data. Biochemical verification of

smoking cessation was not part of my study as it took place solely online. Reflecting back, running the *Stop Smoking Study* with a remote study design allowed me to continue data collection without being incumbered by the Coronavirus pandemic. This also highlights that despite the limitations of remote study designs and the types of data that were collected, there are also many benefits. Aside from continued data collection, there are other advantages of remote research such as participants remaining in their natural environment, flexibility of recruitment from different geographical locations and lower costs.

Whilst the pandemic did not have any major effects on the timeline of my PhD or aspects such as ethics approvals, recruitment and data collection, there were some general difficulties and challenges that I encountered. For example, recruitment took much longer than was initially expected. Participants dropped-out at various stages of the study, including some that stopped responding right after app accounts and log-in details were shared. Maintaining engagement with mobile apps is a known problem that was also evident from my research as not all participants that enrolled into the study used the app for the entire 4-week period. This played a role in extending the recruitment period of my study and making long-term follow-up difficult to achieve within the period of the PhD. It also led to increased pressure regarding the conflicting interests between app developers that are eager to roll-out of version changes and my motives as a researcher. Additionally, although the initial aim was to recruit participants only from the UK, the difficult recruitment process and the nature of the study design led to the inclusion of participants from other geographic regions. Despite experiencing the inherent challenges of conducting remote research and collaborating with companies or organisations with differing interests, the findings of my research can be used to better understand the use and effects of gamification in mobile apps for smoking cessation.

6.5 Chapter Summary

This chapter provides an overview of the main objectives of my research, the methodology adopted to address these objectives and an overarching discussion of the main findings and their implications. My thesis focused on the role of gamification in smoking cessation mobile apps and their effects on critical success factors for quitting, self-efficacy and motivation to quit. My research provided an up-to-date review of smoking cessation apps available on the UK app market, demonstrated that gamification embedded in mobile apps can have positive

effects on self-efficacy and motivation to quit smoking and highlighted the importance and significance of both self-reported and in-app data. The key learnings of this thesis have practical implications for a wide variety of stakeholders; specifically, the outcomes of the research highlight the need for collaboration between behaviour change specialists, mobile app developers, smokers seeking to quit and tobacco control and public health policymakers. Although there are limitations of this research and many unanswered questions for future research to address, my thesis has helped enhance the current understanding of the use of gamification for smoking cessation, and in general, for behaviour change.

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Appendices

Appendix A: Supplementary Tables & Figures

Table A1. Studies investigating impact of smoking cessation apps on cessation outcomes

Study	Type + Location of Study	Name of Mobile App	Smoking Cessation Outcome/Result
Iacoviello et al. (2017)	Single-arm	Clickotine	45% 7-day abstinence and 26% 30-day abstinence reported after 8 weeks
Bricker et al. (2017)[138]	Single-arm	SmartQuit 2.0	21% 7-day abstinence and 11% 30-day abstinence reported after 8 weeks
Ubhi et al. (2015)	Single-arm	SmokeFree28	19% abstinence for 28-day abstinence
Masaki et al. (2019)	Single-arm (app + usual care)	CureApp Smoking Cessation	64% continued abstinence at 6 months for app + usual care
Zeng et al. (2015)	Single-arm	SmartQuit	Fully adhered users 4 times more likely to report 7-day abstinence at 8 weeks compared to users not fully adherent
Bricker et al. (2014)	2-arm (comparing 2 apps)	SmartQuit 1.0 vs. QuitGuide	13% for SmartQuit vs. 8% for QuitGuide for 30-day abstinence reported after 8 weeks
Crane et al. (2018)	2-arm (comparing 2 versions of the same app)	SmokeFree	8.5% abstinence at 12-weeks follow-up for full version of the app vs. 6.5% abstinence for reduced version
Garrison et al. (2020)	2-arm (comparing 2 apps)	Craving to Quit	10% 7-day point prevalence at 6 months for mindfulness app vs. 12% for without mindfulness app

Table A2. Evidence-based smoking cessation guidelines

Five A's Guidelines for Smoking Cessation	
ASK	The mobile app asks the user whether or not they smoke cigarettes and/or use other tobacco products
ADVISE	The mobile app persuades and advises all tobacco users to quit
ASSESS	The mobile app assesses the user's readiness to make a quit attempt. For example, the app can do this by asking questions related to importance or quitting and a self-efficacy.
ASSIST	The mobile app assists or helps the user quit. It can do this in various ways: helping create a quit plan, providing counselling, providing support, recommending medications etc.
ARRANGE	The mobile app arranges follow-up contact with the user or provides referral to specialist support.
Smoking Cessation Guidelines for Self-Help Materials (NICE Institute)	
Harm reduction	Details about harm reduction (e.g. cutting down before stopping, reduction methods, abstain) are provided
Benefits of quitting	An emphasis on the fact that stopping smoking will improve health far more than continuing to smoke, even at a reduced rate (e.g. reduces risk of cancer, COPD, CVD etc.) is evident
Planning a schedule	Advice on how to plan a schedule (e.g. set a quit date, schedule on cutting down) is provided
Strategies to cut down	Advice on strategies to cut down and gradually stop or reduce the amount they smoke is provided
Benefits of nicotine replacement therapy	Benefits of using licensed nicotine-containing products to reduce the harm from smoking (e.g. safe, effective) is provided
Types of nicotine replacement therapy	Information on the type of licensed nicotine-containing products available is provided
How to use nicotine replacement therapy	Information on how to use licensed nicotine-containing products effectively to manage the cravings, mood swings and other effects of nicotine dependency and to prevent relapse is provided
Where to get nicotine replacement therapy	Information on where licensed nicotine-containing products can be purchased and who is able to supply or prescribe them is provided
Further support	Where to get further support (e.g. additional websites, clinics etc.) is provided

Table A3. Linear regression model investigating the association between perceived usefulness of individual game element use and change in self-efficacy between end-study and baseline (N=116)

Factors	Change in Self-efficacy	
	β	95% CI
Age (years)	-0.13	-0.50 to 0.24
Gender		
Male (Referent)		
Female	0.64	-6.49 to 7.77
Nicotine Dependence		
Low (Referent)		
Moderate	-2.54	-9.97 to 4.89
High	1.40	-11.56 to 14.36
Education		
Low (Referent)		
Medium	9.42	-6.57 to 25.31
High	4.51	-9.38 to 18.41
Marital Status		
Single (Referent)		
Married	1.79	-6.68 to 10.26
Usefulness of Logging Diaries	2.39	-2.61 to 7.39
Usefulness of Unlocking Achievements/Badges	-3.04	-7.27 to 1.18
Usefulness of Accessing Progress Dashboard	-0.31	-6.57 to 5.95
Usefulness of Advancing Levels/Stages	6.00[a]	0.59 to 11.41
Usefulness of Sharing Progress with Others	-1.46	-4.98 to 2.05
Constant	-10.75	-36.04 to 14.54

[a]P-value < .05

Table A4. Linear regression model investigating the association between perceived ease of use of individual game element use and change in self-efficacy between end-study and baseline (N=116)

Factors	Change in Self-efficacy	
	β	**95% CI**
Age (years)	-0.12	-0.48 to 0.24
Gender		
Male (Referent)		
Female	-0.95	-8.13 to 6.23
Nicotine Dependence		
Low (Referent)		
Moderate	-0.45	-7.73 to 6.84
High	1.69	-11.45 to 14.84
Education		
Low (Referent)		
Medium	8.06	-8.34 to 24.45
High	2.06	-12.07 to 16.19
Marital Status		
Single (Referent)		
Married	1.86	-6.73 to 10.46
Ease of Use of Logging Diaries	0.72	-3.88 to 5.33
Ease of Use of Unlocking Achievements/Badges	-0.98	-5.67 to 3.72
Ease of Use of Accessing Progress Dashboard	3.20	-2.02 to 8.43
Ease of Use of Advancing Levels/Stages	2.93	-2.56 to 8.42
Ease of Use of Sharing Progress with Others	-3.75	-7.97 to 0.46
Constant	-4.26	-32.59 to 24.08

[a]P-value < .05

Table A5. Testing the effect of self-efficacy as a mediator between gamification and change in motivation to quit (N=116)

Direct, Indirect and Total Effects	Coefficient
Direct Effects	
Gamification → Δ in self-efficacy	5.91 (2.34 to 9.47)[a]
Gamification → Δ in motivation to quit	0.51 (0.17 to 0.84)[a]
Δ in self-efficacy → Δ in motivation to quit	0.03 (0.02 to 0.51)[a]
Indirect Effects	
Gamification → Δ in self-efficacy → Δ in motivation to quit	0.20 (0.05 to 0.36)[a]
Total Effects	
Gamification → Δ in self-efficacy	5.91 (2.34 to 9.47)[a]
Gamification → Δ in motivation to quit	0.71 (0.37 to 1.06)[a]
Δ in self-efficacy → Δ in motivation to quit	0.03 (0.02 to 0.51)[a]

[a]P-value < .05

Table A6. Linear regression model investigating the association between perceived usefulness of individual game element use and change in motivation to quit between end-study and baseline (N=116)

Factors	Change in Motivation to Quit	
	β	95% CI
Age (years)	-0.02	-0.06 to 0.19
Gender		
Male (Referent)		
Female	0.20	-0.52 to 0.91
Nicotine Dependence		
Low (Referent)		
Moderate	-0.26	-1.00 to 0.48
High	-0.02	-1.32 to 1.27
Education		
Low (Referent)		
Medium	-0.54	-2.13 to 1.05
High	-0.60	-1.99 to 0.79
Marital Status		
Single (Referent)		
Married	-0.27	-1.12 to 0.57
Usefulness of Logging Diaries	0.38	-0.12 to 0.88
Usefulness of Unlocking Achievements/Badges	-0.23	-0.65 to 0.20
Usefulness of Accessing Progress Dashboard	-0.20	-0.82 to 0.43
Usefulness of Advancing Levels/Stages	0.46	-0.08 to 1.00
Usefulness of Sharing Progress with Others	0.08	-0.28 to 0.43
Constant	-0.22	-2.74 to 2.31

[a]P-value < .05

Table A7. Linear regression model investigating the association between perceived ease of use of individual game element use and change in motivation to quit between end-study and baseline (N=116)

Factors	Change in Motivation to Quit	
	β	95% CI
Age (years)	-0.02	-0.05 to 0.02
Gender		
Male (Referent)		
Female	0.06	-0.65 to 0.77
Nicotine Dependence		
Low (Referent)		
Moderate	-0.06	-0.78 to 0.66
High	-0.06	-1.35 to 1.24
Education		
Low (Referent)		
Medium	-0.48	-2.09 to 1.14
High	-0.61	-2.00 to 0.79
Marital Status		
Single (Referent)		
Married	-0.21	-1.05 to 0.64
Ease of Use of Logging Diaries	0.48[a]	0.02 to 0.93
Ease of Use of Unlocking Achievements/Badges	-0.23	-0.70 to 0.23
Ease of Use of Accessing Progress Dashboard	0.14	-0.37 to 0.66
Ease of Use of Advancing Levels/Stages	0.24	-0.30 to 0.78
Ease of Use of Sharing Progress with Others	-0.16	-0.57 to 0.26
Constant	-0.44	-3.23 to 2.34

[a]P-value < .05

Table A8. Logistic regression model investigating association between mean perceived usefulness, ease of use and frequency of use of overall gamification with 7-day smoking cessation self-reported at end-study (N=116)

Factors	7-Day Smoking Cessation	
	Odds Ratio	**95% CI**
Age (years)	0.95	0.89 to 1.01
Gender		
Male (Referent)		
Female	1.12	0.36 to 3.51
Nicotine Dependence		
Low (Referent)		
Moderate	1.58	0.48 to 5.26
High	0.49	0.57 to 4.16
Education		
Low (Referent)		
Medium	11.48	0.72 to 182.91
High	7.20	0.63 to 81.78
Marital Status		
Single (Referent)		
Married	4.43[a]	1.27 to 23.24
Mean Frequency of Gamification Use	1.33	0.99 to 1.13
Mean Ease of Use of Gamification	0.95	1.09 to 3.45
Mean Usefulness of Gamification	1.00	0.24 to 4.13
End-Study Self-Efficacy	1.06	0.25 to 3.69
End-Study Motivation to Quit	1.94[a]	0.56 to 3.19
Constant	0.00[a]	0.00 to 0.02

[a]P-value < .05

Table A9. Logistic regression model investigating association between mean perceived usefulness, ease of use and frequency of use of overall gamification with 28-day smoking cessation self-reported at end-study (N=116)

Factors	28-Day Smoking Cessation	
	Odds Ratio	**95% CI**
Age (years)	0.98	0.91 to 1.05
Gender		
Male (Referent)		
Female	1.64	0.45 to 8.08
Nicotine Dependence		
Low (Referent)		
Moderate	1.23	0.27 to 6.41
High	1.69	0.18 to 22.70
Education		
Low (Referent)		
Medium	12.15	0.22 to 100.77
High	2.79	0.14 to 36.41
Marital Status		
Single (Referent)		
Married	4.49	0.95 to 28.34
Mean Frequency of Gamification Use	1.01	0.60 to 0.4.12
Mean Ease of Use of Gamification	0.58	0.10 to 4.41
Mean Usefulness of Gamification	1.65	0.61 to 34.00
End-Study Self-Efficacy	1.01	0.98 to 1.10
End-Study Motivation to Quit	6.40[a]	0.42 to 1.33
Constant	0.00[a]	0.00 to 0.18

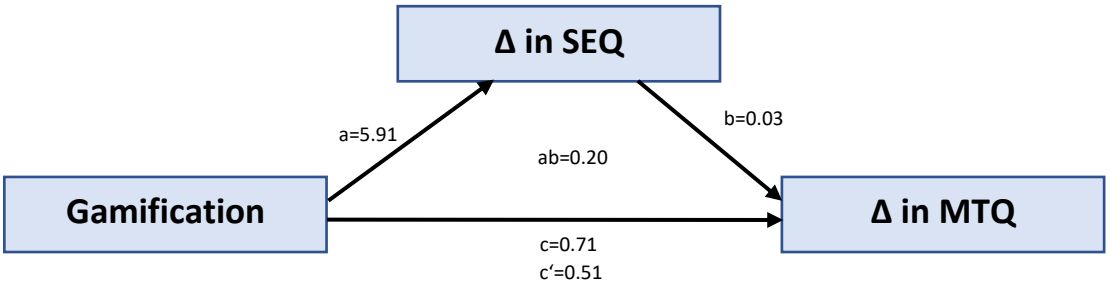
[a]P-value < .05

Table A10. Logistic regression model investigating the association between perceived frequency of individual game element use and self-reported 28-day smoking cessation (N=116)

Factors	28-Day Smoking Cessation	
	Odds Ratio	**95% CI**
Age (years)	0.97	0.90 to 1.05
Gender		
Male (Referent)		
Female	2.37	0.56 to 10.00
Nicotine Dependence		
Low (Referent)		
Moderate	1.30	0.29 to 5.86
High	3.58	0.34 to 38.09
Education		
Low (Referent)		
Medium	7.59	0.35 to 165.77
High	1.87	0.13 to 26.55
Marital Status		
Single (Referent)		
Married	5.97[a]	1.03 to 34.56
Frequency of Logging Diaries	0.85	0.38 to 1.88
Frequency of Unlocking Achievements/Badges	1.32	0.52 to 3.37
Frequency of Accessing Progress Dashboard	0.55	0.17 to 1.76
Frequency of Advancing Levels/Stages	3.08	0.93 to 10.18
Frequency of Sharing Progress with Others	1.08	0.62 to 1.88
Constant	0.00	0.00 to 0.21

[a]P-value < .05

Figure A1. Self-efficacy as a mediator between gamification and change in motivation to quit



a=direct effect of gamification on change in self-efficacy
b=direct effect of change in self-efficacy on change in motivation to quit
ab=indirect/mediation effect of gamification on change in motivation to quit via change in self-efficacy
c= total effect of gamification on change in motivation to quit
c'= direct effect of gamification on change in motivation to quit after controlling for change in self-efficacy

Appendix B: Letter of Approval from Ethics Committee

Imperial College London

Imperial College Research Ethics Committee
Imperial College London
Room 221
Medical School Building
St Marys Campus
London
W2 1PG
Tel: +44 (0)207 594 1872

researchethicscommittee@imperial.ac.uk

26/04/2019

Dear Dr Filippos Filippidis

Study Title:. A prospective observational study investigating the impact of gamified smoking cessation mobile apps on the self-efficacy and motivation of smokers seeking to quit
ICREC reference: 19IC5158

The above study was approved by your Head of Department on 05/04/19 and by the Joint Research Compliance Office on 26/04/19.

Under the Imperial College Research Ethics Committee process, a study that has been reviewed by the Joint Research Compliance Office and Head of Division/Department (or Principal), where no significant ethical issues have been identified in the protocol or ethics application, can be approved without requiring it to go to full committee.

Documents
The documents reviewed were:

- ICREC Application form (v1.1 25/04/19)
- Protocol (v1.1 25/04/19)
- Poster (v1.1 25/04/19)
- Participant Information Sheet (v1.1 25/04/19)
- Consent Form (v1.1 25/04/19)
- Screening (v1.1 25/04/19)
- Installations Instructions (v1.1 25/04/19)
- Baseline (v1.1 25/04/19)
- Self-efficacy (v1.1 25/04/19)
- Motivation (v1.1 25/04/19)
- Usefulness (v1.1 25/04/19)
- Ease of use (v1.1 25/04/19)
- Frequency (v1.1 25/04/19)
- Cessation (v1.1 25/04/19)
- SUS (v1.1 25/04/19)
- AppMetrics (v1.1 25/04/19)
- Recruitment (v1.1 25/04/19)

Yours sincerely,

Ruth Nicholson,
Head of Research Governance and Integrity,
Imperial College London

Appendix C: Screening

Department of Primary Care and
Public Health, Imperial College London
Reynolds Building, St Dunstan's Road
London, W6 RP

A Prospective Observational Study on Gamified Mobile Applications for Smoking Cessation Interventions

SCREENING QUESTIONNAIRE – The Stop Smoking Study

Version 1.1 (25th April 2019)

Thank you for your interest in participating in this study on smoking cessation programmes delivered via smartphones. In order to assess your eligibility, please indicate yes or no for the following statements provided below.

Statement	Yes	No
I am 18 years or older		
I am proficient in the English language		
I am a smoker. I have smoked at least 100 cigarettes in my lifetime and I currently smoke at least one cigarette a day		
I am trying or willing to quit smoking in the next 30 days		
I am not using other forms of smoking cessation treatment. This includes nicotine replacement products, medications, other pharmacological treatment and any other interventions such as e-cigarettes		
I have not previously used the mobile application Kwit or Quit Genius to help me quit smoking		
I am not currently using any mobile app for smoking cessation		
I have an Apple iPhone (5th generation or higher) or Android phone (version 18 or higher)		
I am fine with installing a mobile application for smoking cessation on my smartphone		
I am willing and able to use a mobile application for smoking cessation for a minimum of 4 weeks and fill out relevant questionnaires online		
I am not diagnosed with a mental health condition		
I am willing and able to provide informed consent.		

Appendix D: Consent Form

Department of Primary Care and
Public Health, Imperial College London
Reynolds Building, St Dunstan's Road
London, W6 RP

A Prospective Observational Study on Gamified Mobile Applications for Smoking Cessation Interventions

CONSENT FORM – The Stop Smoking Study

Version 1.1 (25th April 2019)

Please initial box

1. I confirm that I have read and I understand the participant information sheet dated 25th April 2019, version 1.1 for the above study and have had the opportunity to ask questions which have been answered fully.	
2. I understand that my participation is voluntary and I am free to withdraw at any time, without giving any reason and without my legal rights being affected.	
3. I agree that my compensation for participating in the study is free access to a smoking cessation app for the duration of the study and a chance to win a £50 Amazon voucher.	
4. I agree that my anonymised study data will be used in the current and future ethically approved studies.	
5. I am happy that my contact details will be securely stored with the responsible researchers from Imperial College London and to be contacted for related research studies.	
6. I agree to install a mobile app for smoking cessation which has been assigned to me by the responsible Imperial College London researcher.	
7. I agree for the app developer to share my in-app data (e.g. number of logins, time spent on app, engagement with features etc.) with the responsible individuals from Imperial College London.	
8. I agree to take part in the study.	

_____	_____	_____
Name of Participant	Date	Signature
_____	_____	_____
Name of Investigator	Date	Signature

1 copy for participant; 1 copy for Investigator

Appendix E: Participant Information Sheet

Department of Primary Care and
Public Health, Imperial College London
Reynolds Building, St Dunstan's Road
London, W6 RP

A Prospective Observational Study on Gamified Mobile Applications for Smoking Cessation Interventions

PARTICIPANT INFORMATION SHEET – The Stop Smoking Study

(Version 1.1, 25th April 2019)

Thank you for your interest in participating in this study on using mobile apps to quit smoking. Before agreeing to participate, please read through the following information in order to understand the research, its purpose and value, and your involvement.

If you have any unanswered questions, are unclear about any aspect of this study, or would like further information, please feel free to contact Nikita Rajani via nikita.rajani14@imperial.ac.uk. Please take your time to decide whether or not you wish to participate.

What is the purpose of your research?

The purpose of this study is to investigate how certain features and elements in mobile apps designed to help people quit smoking affect a smoker's confidence in their ability to quit and their motivation to quit. The study also aims to examine whether certain features and elements of mobile apps improve the likelihood of successfully quitting.

Can I participate in this study?

In order to participate in the study, you need to meet the following eligibility criteria:

- I am 18 years or older
- I am proficient in the English language
- I am a smoker. I have smoked at least 100 cigarettes in my lifetime and I currently smoke at least one cigarette a day.
- I am trying or willing to quit smoking in the next 30 days
- I am not using other forms of smoking cessation treatment. This includes nicotine replacement products, medications, other pharmacological treatment and any other interventions such as e-cigarettes
- I have not previously used the mobile application Kwit or Quit Genius
- I am not currently using any mobile app for smoking cessation
- I am fine with installing a mobile application for smoking cessation on my smartphone and have access to mobile data
- I am not diagnosed with a mental health condition

What will I be asked to do?

If you decide to participate, you will be assigned an unidentifiable study identification number and be asked to sign an electronic consent form. You are asked install and use a smoking cessation mobile application assigned to you for a total of 4 weeks. Before downloading the app, 2 weeks after using the app, and 4 weeks after using the app, you will be asked to fill out questionnaires about your smoking status, confidence in your ability to quit, motivation to quit, and thoughts about certain features and elements of the mobile application. All questionnaires can be completed online; there is no need for in-person contact. Furthermore, your app usage data will be shared with the responsible Imperial College London researchers from the mobile app developers.

What happens when I complete the study? Will I be reimbursed?

You will successfully complete the study when you:

- Use the smoking cessation mobile app for the entire duration of the study
- Complete all online questionnaires

As reimbursement, you gain access to the smoking cessation mobile app for free throughout the duration of the study. This app would otherwise have a fee for usage. You will also get a chance to win a £50 Amazon voucher.

What are the possible benefits of taking part?

Participating in the study may result in successfully quitting smoking and therefore adopting a healthier lifestyle. Your contribution will help researchers better understand health behaviour change strategies for smoking.

Will my taking part in this study be kept confidential?

Online questionnaire will be delivered to you using Qualtrics. Qualtrics is a secure online Research Suite survey tool that follows HITECH (Health Information Technology for Economic and Clinical Health Act) requirements to properly protect data and follow best security practices.

Neither questionnaires nor data collected by apps will contain your name. The app developers will only share completely anonymised data with Imperial College London. You will not be identified by name in any report of results, nor will the report contain any statements that can be traced to any individual. We will not inform anyone that you participated in this study.

LEGAL BASIS

As a university we use personally-identifiable information to conduct research to improve health, care and services. As a publicly-funded organisation, we have to ensure that it is in the public interest when we use personally-identifiable information from people who have agreed to take part in research. This means that when you agree to take part in a research study, we will use your data in the ways needed to conduct and analyse the research study.

Health and care research should serve the public interest, which means that we have to demonstrate that our research serves the interests of society as a whole. We do this by following the UK Policy Framework for Health and Social Care Research.

Imperial College London researchers will use your name and contact details to contact you about the research study, and make sure that relevant information about the study is recorded for your care, and to oversee the quality of the study. Individuals from Imperial College London and regulatory organisations may look at your medical and research records to check the accuracy of the research study. The only people at Imperial College London who will have access to information that identifies you will be people who need to contact you regarding the study or audit the data collection process. The people who analyse the information will not be able to identify you and will not be able to find out your name or contact details.

Imperial College London will keep identifiable information about you from this study 10 years after the study has finished.

Am I allowed to withdraw from the study?

It is up to you whether you would like to participate in the study or not. You are allowed to withdraw from the study at any point that you wish without having to give a reason.

What will happen to the results of the research study?

Data collected by questionnaires and the app will be analysed to evaluate the impact of features and elements of the mobile app on quitting confidence and motivation to quit. The summarised and anonymised feedback will be shared with the app developers, which can aid them in creating a better app. We will also write up the results in a scientific manuscript to share our learnings. The data collected in this study will be securely stored for a minimum of 10 years at the Imperial College London.

Who has reviewed the study?

The Joint Research Compliance Office (JRCO) has reviewed and approved the study.

Who can I contact if I have any problems or queries?

Nikita Rajani
PhD Student
Department of Primary Care and Public Health
Imperial College London
Email: nikita.rajani14@imperial.ac.uk, Telephone: 07427615928

Appendix F: Recruitment Material

1) Recruitment Email:

Dear <Insert Name>

Are you interested in **quitting smoking?** Do you want to make a healthy change to your lifestyle? Imperial College London is conducting **"The Stop Smoking Study"** to help smokers quit smoking using mobile apps.

As a participant, you will be asked to install a **mobile application** onto your mobile phone and use a smoking cessation programme for 4 weeks. You will be asked to fill out questionnaires before, during and after the programme. You will **not be required** to meet in person at any point of the study.

Sign up now and gain **FREE ACCESS** to a smoking cessation programme as well as a chance to win a **£50 Amazon voucher**!

Either send me an email directly if you are interested in the study or use this link to sign up:

https://imperial.eu.qualtrics.com/jfe/form/SV_1LYOvRAKTakJVat

Best wishes,

Nikita Rajani
PhD Student
Department of Primary Care and Public Health
Imperial College London

2) Facebook/Instagram Post:

Sign up for THE STOP SMOKING STUDY and quit your bad habit now! Install and use a smoking cessation app for 4 weeks, fill out some questionnaires and gain a chance to win a £50 Amazon voucher! If you are interested, scan the QR code below or email nikita.rajani14@imperial.ac.uk

3) Posters

Imperial College London

Appendix 1. Recruitment Poster (Version 1.1, 25th April 2019)

DO YOU WANT TO QUIT SMOKING?

Are you interested in **quitting smoking?** Do you want to make a healthy change to your lifestyle? Imperial College London is conducting **"The Stop Smoking Study"** to help smokers quit smoking using mobile apps.

As a participant, you will be asked to install a **mobile application** onto your mobile phone and use a smoking cessation programme for 4 weeks. You will be asked to fill out questionnaires before, during and after the programme. You will **not be required** to meet in person at any point of the study.

Sign up now and gain **FREE ACCESS** to a smoking cessation programme as well as a chance to win a **£50 Amazon voucher!**

For more information, **scan the QR code** and fill out the contact form or **send an email** to Nikita Rajani!

Are you interested or would like more information?
Please contact Nikita Rajani on nikita.rajani14@imperial.ac.uk

nikita.rajani14@imperial.ac.uk | nikita.rajani14@imperial.ac.uk | nikita.rajani14@imperial.ac.uk | nikita.rajani14@imperial.ac.uk | nikita.rajani14@imperial.ac.uk | nikita.rajani14@imperial.ac.uk | nikita.rajani14@imperial.ac.uk | nikita.rajani14@imperial.ac.uk | nikita.rajani14@imperial.ac.uk | nikita.rajani14@imperial.ac.uk | nikita.rajani14@imperial.ac.uk

Imperial College London

ICREC Reference: 19IC5158
Version 1.0, 5th April 2019

Scan the QR code
send an email to **Nikita Rajani!**

Do you want to Quit Smoking

Sign up now and gain FREE ACCESS to a smoking cessation programme as well as a chance to win a £50 Amazon voucher!

Quit now

As a participant, you will be asked to install a mobile application onto your mobile phone and use a smoking cessation programme for 4 weeks. You will be asked to fill out questionnaires before, during and after the programme. You will not be required to meet in person at any point of the study.

Are you interested or would like more information?
Please contact Nikita Rajani on nikita.rajani14@imperial.ac.uk

Appendix G: App Installation Instructions

For Kwit Participants

Dear Participant,

Thank you for your interest in participating in the Stop Smoking Study. Please follow the below instructions in order to install the mobile application onto your smartphone. The username and password provided will only be valid for 48 hours, so please redeem and begin using the app as soon as possible!

Android Users:

1) Search for the mobile app “Kwit-Quit Smoking for Good” by the developers Kwit SAS on your Google Play Store. Or alternatively, click on the link below:

https://play.google.com/store/apps/details?id=fr.kwit.android&hl=en

2) Install and open the mobile application.

3) Click on “Log in”

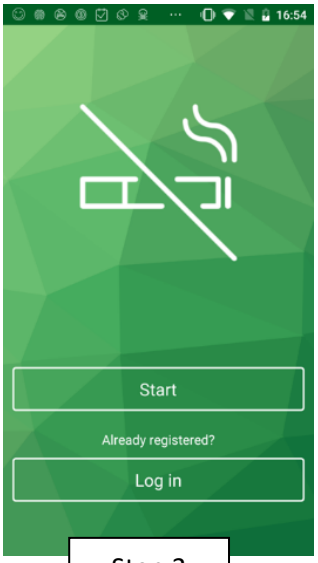
4) Enter in the email/username and password provided below and click on “log in”

Username: <insert username assigned by Kwit>

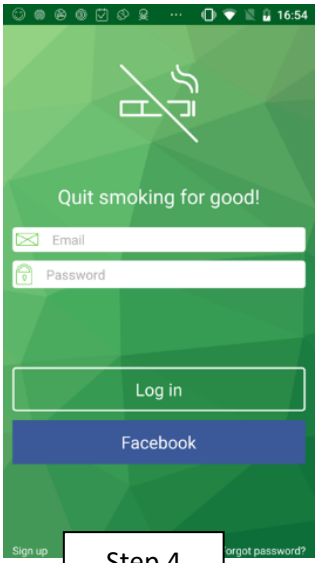
Password: <insert password assigned by Kwit>

5) Input your smoking habits into the screen and click on “Confirm”.

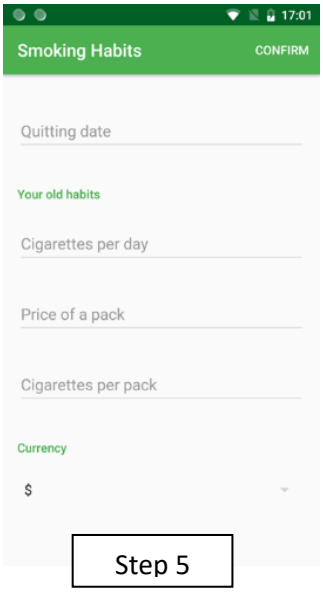
6) You now have access to all the features of the app! Good luck on your quit journey!



Step 3



Step 4



Step 5

iOS Users:

1) Search for the mobile app “Kwit-Quit Smoking for Good” by the developers Kwit SAS on your Apple Store. Or alternatively, click on the link below:

https://itunes.apple.com/us/app/kwit-quit-smoking-cigarettes/id525441365?mt=8

2) Install and open the mobile application.

3) Click on “Already an account? Sign in”

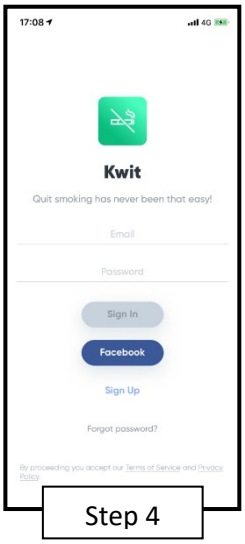
4) Enter in the email/username and password provided below and click on “sign in”

Username: <insert username assigned by Kwit>

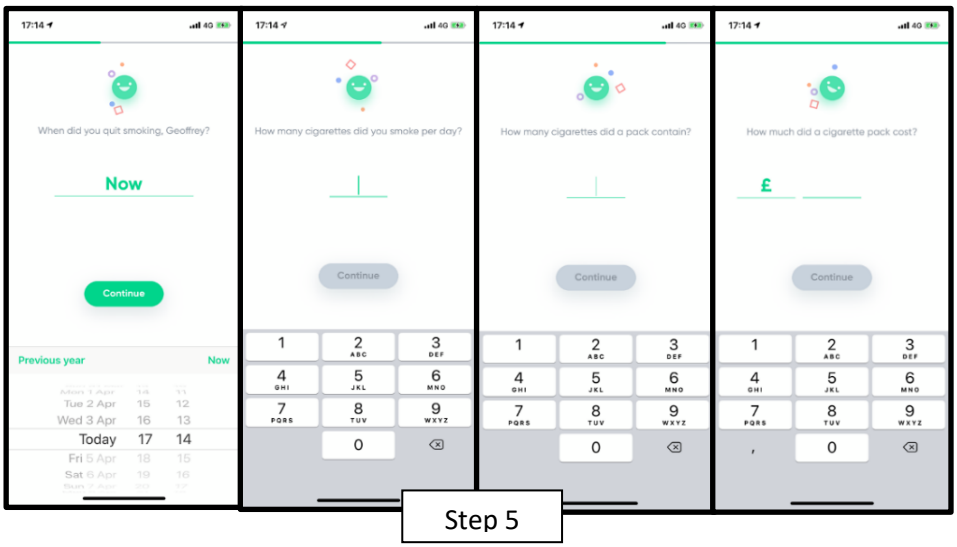
Password: <insert password assigned by Kwit>

5) Enter your former smoking habits and quit date

6) Click on continue. You should have access to all features. Please use the app as you normally would for your quit journey! Good luck!



Step 4



Step 5

For Quit Genius Participants

Dear Participant,

Thank you for your interest in participating in the Stop Smoking Study. Please follow the below instructions in order to install the mobile application onto your smartphone. The username and password provided will only be valid for 24 hours, so please redeem and begin using the app as soon as possible!

1) Search for the mobile app "Quit Genius" by the developers Digital Therapeutics on your Google Play or Apple Store. Or alternatively, click on the link below depending on whether you use the Apple Store or Google Play Store:

> **Google Play Store:**
> https://play.google.com/store/apps/details?id=co.digithera.v2.quitgenius
>
> **Apple Store:** https://itunes.apple.com/gb/app/quit-genius-quit-smoking/id1234288038?mt=8

2) Install and open the mobile application.

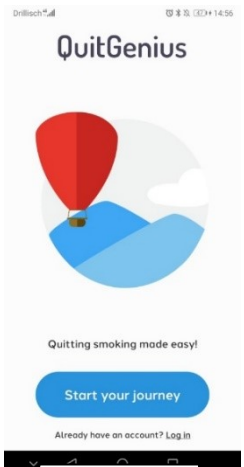
3) Click on "Already have an account? Log in" with the details below:

> **Username:** <insert password assigned by Quit Genius>
>
> **Password:** <insert password assigned by Quit Genius>

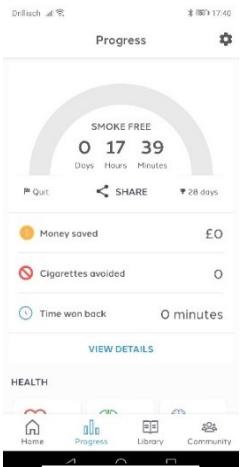
4) Click on the "Progress" tab at the bottom of the screen.

5) Click on "Your Quit Date" and adjust it to when you would like to quit smoking. Click on "Continue". If anything has not updated based on your adjusted quit date, please sign out and sign in again. You can sign in by clicking on the settings icon under "Progress" and then clicking on "Log out".

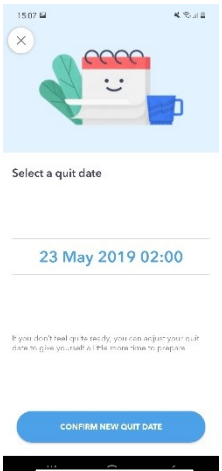
6) You should now successfully logged on to the app and have access to all features. Please use the app as you normally would for your quit journey! Good luck!



Step 3



Step 4



Step 5

Appendix H: Self-Efficacy Questionnaire (SEQ-12)

The following are some situations in which certain people might be tempted to smoke. Please indicate whether you are sure that you could refrain from smoking in each situation using one of the following answers:

1 = Not at all sure, 2 = Not very sure, 3 = More or less sure, 4 = Fairly sure, 5 = Absolutely sure

Situation	Please indicate how sure you are from refraining to smoke by selecting a number from 1 to 5 (1 being not at all sure and 5 being absolutely sure)
When I feel nervous	
When I feel depressed	
When I am angry	
When I feel very anxious	
When I want to think about a difficult problem	
When I feel the urge to smoke	
When having a drink with friends	
When celebrating something	
When drinking beer, wine, or other spirits	
When I am with smoker's	
After a meal	
When having coffee or tea	

Appendix I: Motivation to Quit Questionnaire

The next set of questions tells us about your motivation to stop smoking. Please circle one response for each of the questions provided below.

1. How important is it to you to give up smoking altogether at this attempt?
   - ☐ Desperately important
   - ☐ Very important
   - ☐ Quite important
   - ☐ Not all that important
2. How determined are you to give up smoking at this attempt?
   - ☐ Extremely determined
   - ☐ Very determined
   - ☐ Quite determined
   - ☐ Not all that determined

Appendix J: Self-Reported Gamification Questionnaire

A) Perceived Usefulness

Quit Genius Users: There is an increased use of game elements and social engagement in today's mobile health apps, like earning rewards in the form of badges or achievement for completing activity goals and interacting with other users. In your opinion, how useful do you perceive the following features whilst using Quit Genius during your quit attempt?

	Strongly agree	Agree	Neither agree/disagree	Disagree	Strongly disagree
Statement					
1. Allowing me to set my own goal (i.e. quit date) is useful for my quit attempt.	1	2	3	4	5
2. Breaking down the quit journey into consecutive stages and incremental steps is useful for my quit attempt.	1	2	3	4	5
3. Providing me with badges and trophies is useful for my quit attempt.	1	2	3	4	5
4. Being able to compare myself and share my progress with others is useful for my quit attempt.	1	2	3	4	5
5. Checking my progress and tracking my metrics under the "Stats" page is useful for my quit attempt.	1	2	3	4	5
6. Logging entries into my "Smoking diary" is useful for my quit attempt.	1	2	3	4	5
7. I find the mobile app Quit Genius useful to quit smoking.	1	2	3	4	5

Kwit Users: There is an increased use of game elements and social engagement in today's mobile health apps, like earning rewards in the form of badges or achievement for completing activity goals and interacting with other users. In your opinion, how useful do you perceive the following features whilst using Kwit during your quit attempt?

	Strongly agree	Agree	Neither agree/disagree	Disagree	Strongly disagree
Statement					
1. Logging and tracking my entries into the diary is useful for my quit attempt.	1	2	3	4	5
2. Breaking down the quit journey into achievements that need to be unlocked to advance to the next is useful for my quit attempt.	1	2	3	4	5
3. The progress dashboard where I can track my metrics constantly is useful for my quit attempt.	1	2	3	4	5
4. Being able to share my achievement and progress with others is useful for my quit attempt.	1	2	3	4	5
5. Advancing from one level to another is useful for my quit attempt.	1	2	3	4	5
6. The motivational cards are useful for my quit attempt.	1	2	3	4	5
7. I find the mobile app Quit Genius useful to quit smoking.	1	2	3	4	5

B) Perceived Ease of Use

Quit Genius Users: There is an increased use of gaming mechanics and social engagement in today's mobile health apps, like earning rewards in the form of badges or achievement for completing activity goals and interacting with other users. In your opinion, how easy to use do you perceive the following mechanics on the Quit Genius app?

	Strongly agree	Agree	Neither agree/disagree	Disagree	Strongly disagree
Statement					
1. Setting my own goal (i.e. quit date) is easy to do on the Quit Genius app.	1	2	3	4	5
2. The breakdown of the quit journey into consecutive stages and incremental steps is easy to follow on the Quit Genius app.	1	2	3	4	5
3. Viewing and accessing badges and trophies is easy to do on the Quit Genius app.	1	2	3	4	5
4. Being able to share my progress with others is easy to do on the Quit Genius app.	1	2	3	4	5
5. It is easy to check my progress and track my metrics under "Stats" on the Quit Genius app.	1	2	3	4	5
6. It is easy to log entries into my "Smoking diary" on the Quit Genius app.	1	2	3	4	5
7. I find the mobile app Quit Genius easy to use.	1	2	3	4	5

Kwit Users: There is an increased use of gaming mechanics and social engagement in today's mobile health apps, like earning rewards in the form of badges or achievement for completing activity goals and interacting with other users. In your opinion, how easy to use do you perceive the following mechanics on the Kwit app?

Statement	Strongly agree	Agree	Neither agree/disagree	Disagree	Strongly disagree
1. Logging and tracking my entries into the diary is easy to do on the Kwit app.	1	2	3	4	5
2. Unlocking consecutive achievements is easy to do on the Kwit app.	1	2	3	4	5
3. It is easy to use the progress dashboard to track my metrics on the Kwit app.	1	2	3	4	5
4. Being able to share my achievement and progress with others is easy to do on the Kwit app.	1	2	3	4	5
5. It is easy to view and understand which level I am on the Kwit app.	1	2	3	4	5
6. The motivational cards are easy to access on the Kwit app.	1	2	3	4	5
7. I find the mobile app Kwit easy to use.	1	2	3	4	5

C) Perceived Frequency of Use

Quit Genius Users: How frequently did you engage with the following features of the app?

	Never	Rarely/Seldom	Sometimes	Often	Almost Always
Feature					
1. Goal setting	1	2	3	4	5
2. Stages/steps	1	2	3	4	5
3. Viewing badges	1	2	3	4	5
4. Sharing progress	1	2	3	4	5
5. Checking my progress under "Stats"	1	2	3	4	5
6. Logging entries into my "Smoking diary"	1	2	3	4	5

Kwit Users: How frequently did you engage with the following features of the app?

	Never	Rarely/Seldom	Sometimes	Often	Almost Always
Feature					
1. Logging and tracking my entries into the diary	1	2	3	4	5
2. Unlocking achievements	1	2	3	4	5
3. Accessing the progress dashboard	1	2	3	4	5
4. Sharing my achievements with others	1	2	3	4	5
5. Checking which level I am on	1	2	3	4	5
6. Reading motivation cards	1	2	3	4	5

Appendix K: Fagerström Test for Nicotine Dependence

1. How soon after waking do you smoke your first cigarette?
    - ☐ Within 5 minutes
    - ☐ 6 – 30 minutes
    - ☐ 31 – 60 minutes
    - ☐ After 60 minutes
2. Do you find it difficult to refrain from smoking in places where it is forbidden?
    - ☐ Yes
    - ☐ No
3. Which cigarette would you hate to give up?
    - ☐ The first in the morning
    - ☐ Any other
4. How many cigaretttes a day do you smoke?
    - ☐ Less than 10
    - ☐ 11 – 20
    - ☐ 21 – 30
    - ☐ 31 or more
5. Do you smoke more frequently in the morning?
    - ☐ Yes
    - ☐ No
6. Do you smoke even if you are sick in bed most of the day?
    - ☐ Yes
    - ☐ No

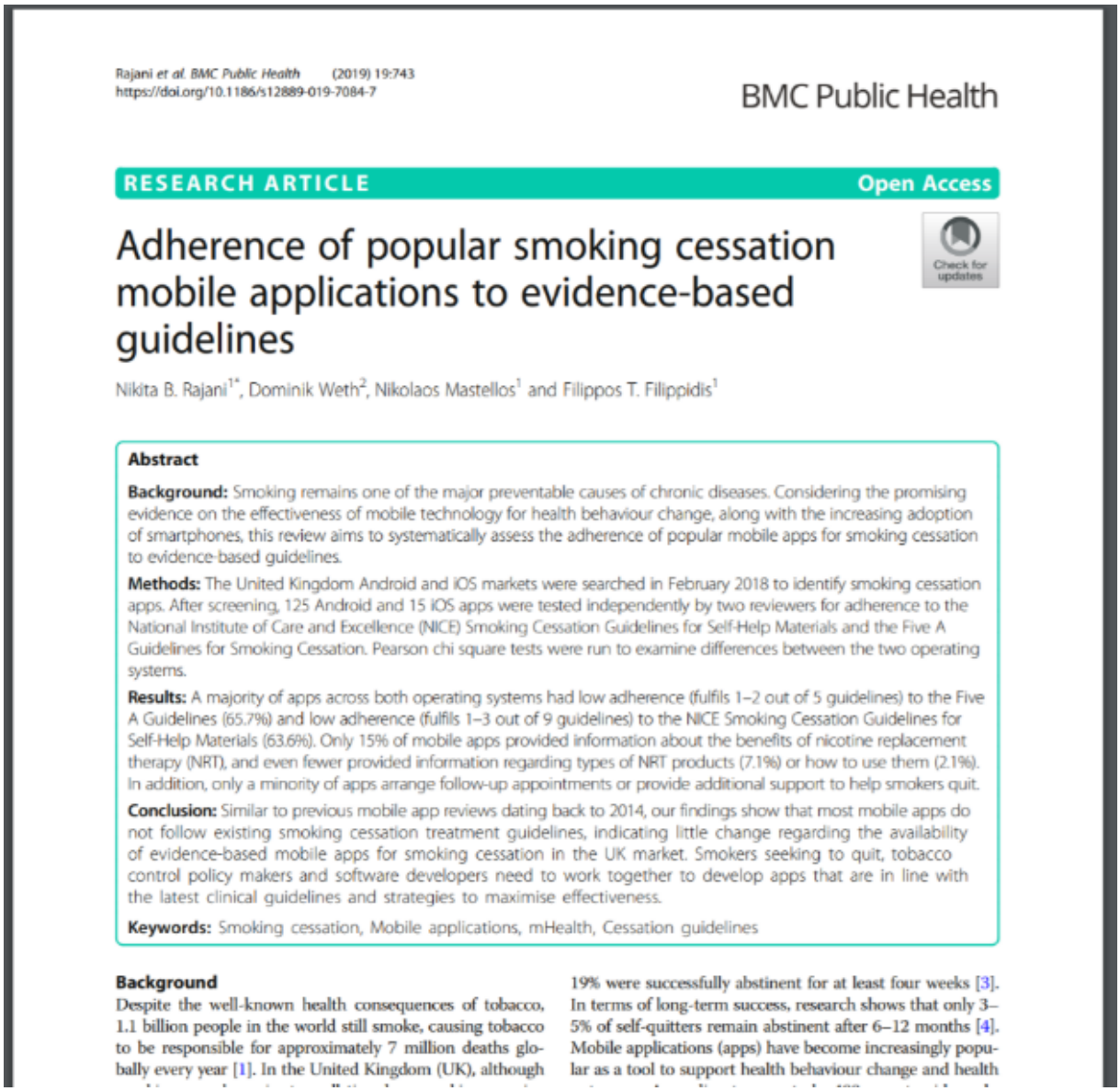
Appendix L: System Usability Scale

Statement	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
I think I would like to use this app frequently.	1	2	3	4	5
I found the app unnecessarily complex.	1	2	3	4	5
I thought the app was easy to use.	1	2	3	4	5
I think that I would need the support of a technical person to be able to use this app.	1	2	3	4	5
I found the various functions in this app well-integrated.	1	2	3	4	5
I thought there was too much inconsistency in this app.	1	2	3	4	5
I would imagine that most people would learn to use this app very quickly.	1	2	3	4	5
I found the app very cumbersome to use.	1	2	3	4	5
I felt very confident using the app.	1	2	3	4	5
I needed to learn a lot of things before I could get going with this app.	1	2	3	4	5

Appendix M: Published Papers

Paper 1: BMC Public Health

Rajani NB, Weth D, Mastellos N, Filippidis FT. Adherence of popular smoking cessation mobile applications to evidence-based guidelines. *BMC Public Health.* 2019; 19 (1): 743. Available from: doi: 10.1186/s12889-019-7084-7.



Rajani et al. BMC Public Health (2019) 19:743
https://doi.org/10.1186/s12889-019-7084-7

BMC Public Health

RESEARCH ARTICLE Open Access

Adherence of popular smoking cessation mobile applications to evidence-based guidelines

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Abstract

Background: Smoking remains one of the major preventable causes of chronic diseases. Considering the promising evidence on the effectiveness of mobile technology for health behaviour change, along with the increasing adoption of smartphones, this review aims to systematically assess the adherence of popular mobile apps for smoking cessation to evidence-based guidelines.

Methods: The United Kingdom Android and iOS markets were searched in February 2018 to identify smoking cessation apps. After screening, 125 Android and 15 iOS apps were tested independently by two reviewers for adherence to the National Institute of Care and Excellence (NICE) Smoking Cessation Guidelines for Self-Help Materials and the Five A Guidelines for Smoking Cessation. Pearson chi square tests were run to examine differences between the two operating systems.

Results: A majority of apps across both operating systems had low adherence (fulfils 1–2 out of 5 guidelines) to the Five A Guidelines (65.7%) and low adherence (fulfils 1–3 out of 9 guidelines) to the NICE Smoking Cessation Guidelines for Self-Help Materials (63.6%). Only 15% of mobile apps provided information about the benefits of nicotine replacement therapy (NRT), and even fewer provided information regarding types of NRT products (7.1%) or how to use them (2.1%). In addition, only a minority of apps arrange follow-up appointments or provide additional support to help smokers quit.

Conclusion: Similar to previous mobile app reviews dating back to 2014, our findings show that most mobile apps do not follow existing smoking cessation treatment guidelines, indicating little change regarding the availability of evidence-based mobile apps for smoking cessation in the UK market. Smokers seeking to quit, tobacco control policy makers and software developers need to work together to develop apps that are in line with the latest clinical guidelines and strategies to maximise effectiveness.

Keywords: Smoking cessation, Mobile applications, mHealth, Cessation guidelines

Background

Despite the well-known health consequences of tobacco, 1.1 billion people in the world still smoke, causing tobacco to be responsible for approximately 7 million deaths globally every year [1]. In the United Kingdom (UK), although 19% were successfully abstinent for at least four weeks [3]. In terms of long-term success, research shows that only 3–5% of self-quitters remain abstinent after 6–12 months [4]. Mobile applications (apps) have become increasingly popular as a tool to support health behaviour change and health

Paper 2: BMJ Public Open

Rajani NB, Weth D, Mastellos N, Filippidis FT. Use of gamification strategies and tactics in mobile applications for smoking cessation: a review of the UK mobile app market. *BMJ Open.* 2019; 9 (6): e027883. Available from: doi: 10.1136/bmjopen-2018-027883

Open access Research

BMJ Open

Use of gamification strategies and tactics in mobile applications for smoking cessation: a review of the UK mobile app market

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To cite: Rajani NB, Weth D, Mastellos N, *et al*. Use of gamification strategies and tactics in mobile applications for smoking cessation: a review of the UK mobile app market. *BMJ Open* 2019;**9**:e027883. doi:10.1136/bmjopen-2018-027883

► Prepublication history and additional material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2018-027883).

Received 13 November 2018
Revised 15 March 2019
Accepted 16 May 2019

ABSTRACT

Objective Mobile phone-based interventions have been proven to be effective tools for smoking cessation, at least in the short term. Gamification, that is, the use of game-design elements in a non-game context, has been associated with increased engagement and motivation, critical success factors for long-term success of mobile Health solutions. However, to date, no app review has examined the use of gamification in smoking cessation mobile apps. Our review aims to examine and quantify the use of gamification strategies (broad principles) and tactics (on-screen features) among existing mobile apps for smoking cessation in the UK.

Methods The UK Android and iOS markets were searched in February 2018 to identify smoking cessation apps. 125 Android and 15 iOS apps were tested independently by two reviewers for primary functionalities, adherence to Five A smoking cessation guidelines, and adoption of gamification strategies and tactics. We examined differences between platforms with χ^2 tests. Correlation coefficients were calculated to explore the relationship between adherence to guidelines and gamification.

Results The most common functionality of the 140 mobile apps we reviewed allowed users to track the days since/until the quit date (86.4%). The most popular gamification strategy across both platforms was performance feedback (91.4%). The majority of apps adopted a medium level of gamification strategies (55.0%) and tactics (64.3%). Few adopted high levels of gamification strategies (6.4%) or tactics (5.0%). No statistically significant differences between the two platforms were found regarding level of gamification ($p>0.05$) and weak correlations were found between adherence to Five A's and gamification strategies ($r=0.38$) and tactics ($r=0.26$).

Conclusion The findings of this review show that a high

Strengths and limitations of this study

- The study had a sample of 140 mobile apps for smoking cessation in the UK iOS and Google Play store.
- Since the architecture used to operationalise gamification was developed through review of taxonomies from both academic and non-academic sources, the architecture is representative of existing literature.
- The exclusion of apps with less than a 4-star rating or fewer than 5 ratings resulted in the omission of a large number of iOS apps, limiting the generalisability of the findings for the iOS store.
- Certain app functionalities and gamification elements that are only visible or activated on long-term use may not have been identified by our review.

death and disability within the UK.[2] Although behavioural support along with pharmacological treatments is evidently the most effective method for smoking cessation, not all individuals seeking to quit are able or willing to seek face-to-face support.[3] The number of individuals using smoking cessation services provided by the National Health Service in the UK is continuously falling,[4] a trend observed in multiple European countries.[5] The decline in use of stop smoking services is likely to be attributed to access issues in light of significant public health budget cuts.[6] On the other hand, due to increased

Paper 3: JMIR mHealth and uHealth

Rajani NB, Mastellos N, Filippidis FT. Self-Efficacy and Motivation to Quit of Smokers Seeking to Quit: Quantitative Assessment of Smoking Cessation Mobile Apps. *JMIR mHealth and uHealth.* 2021; 9 (4): e25030. Available from: doi: 10.2196/25030 .

Original Paper

Self-Efficacy and Motivation to Quit of Smokers Seeking to Quit: Quantitative Assessment of Smoking Cessation Mobile Apps

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Abstract

Background: Decreasing trends in the number of individuals accessing face-to-face support are leaving a significant gap in the treatment options for smokers seeking to quit. Face-to-face behavioral support and other interventions attempt to target psychological factors such as the self-efficacy and motivation to quit of smokers, as these factors are associated with an increased likelihood of making quit attempts and successfully quitting. Although digital interventions, such as smoking cessation mobile apps, could provide a promising avenue to bridge the growing treatment gap, little is known about their impact on psychological factors that are vital for smoking cessation.

Objective: This study aims to better understand the possible impact of smoking cessation mobile apps on important factors for successful cessation, such as self-efficacy and motivation to quit. Our aim is to assess the self-efficacy and motivation to quit levels of smokers before and after the use of smoking cessation mobile apps.

Methods: Smokers seeking to quit were recruited to participate in a 4-week app-based study. After screening, eligible participants were asked to use a mobile app (Kwit or Quit Genius). The smoking self-efficacy questionnaire and the motivation to stop smoking scale were used to measure the self-efficacy and motivation to quit, respectively. Both were assessed at baseline (before app use), midstudy (2 weeks after app use), and end-study (4 weeks after app use). Paired sample two-tailed *t* tests were used to investigate whether differences in self-efficacy and motivation between study time points were statistically significant. Linear regression models investigated associations between change in self-efficacy and change in motivation to quit before and after app use with age, gender, and nicotine dependence.

Paper 4: JMIR Serious Games

Rajani NB, Mastellos N, Filippidis FT. Impact of Gamification on the Self-Efficacy and Motivation to Quit of Smokers: Observational Study of Two Gamified Smoking Cessation Mobile Apps. *JMIR serious games.* 2021; 9 (2): e27290. Available from: doi: 10.2196/27290

Original Paper

Impact of Gamification on the Self-Efficacy and Motivation to Quit of Smokers: Observational Study of Two Gamified Smoking Cessation Mobile Apps

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Abstract

Background: The proportion of smokers making quit attempts and the proportion of smokers successfully quitting have been decreasing over the past few years. Previous studies have shown that smokers with high self-efficacy and motivation to quit have an increased likelihood of quitting and staying quit. Consequently, further research on strategies that can improve the self-efficacy and motivation of smokers seeking to quit could lead to substantially higher cessation rates. Some studies have found that gamification can positively impact the cognitive components of behavioral change, including self-efficacy and motivation. However, the impact of gamification in the context of smoking cessation and mobile health has been sparsely investigated.

Objective: This study aims to examine the association between perceived usefulness, perceived ease of use, and frequency of use of gamification features embedded in smoking cessation apps on self-efficacy and motivation to quit smoking.

Methods: Participants were assigned to use 1 of the 2 mobile apps for a duration of 4 weeks. App-based questionnaires were provided to participants before app use and 2 weeks and 4 weeks after they started using the app. Gamification was quantitatively operationalized based on the Cugelman gamification framework and concepts from the technology acceptance model. The mean values of perceived frequency, ease of use, and usefulness of gamification features were calculated at midstudy and end-study. Two linear regression models were used to investigate the impact of gamification on self-efficacy and motivation to quit.

Results: A total of 116 participants completed the study. The mean self-efficacy increased from 37.38 (SD 13.3) to 42.47 (SD 11.5) points and motivation to quit increased from 5.94 (SD 1.4) to 6.32 (SD 1.7) points after app use. *Goal setting* was perceived to be the most useful gamification feature, whereas *sharing* was perceived to be the least useful. Participants self-reported that