Gamification – A Marketing Strategy: Empirical investigations in the context of physical activity

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Abstract

Gamification is fast becoming a mainstay in marketing practice to enhance the service offering with game-like experiences, ostensibly to support the users' value creation. However, understanding how gamification can lead to enhanced value remains incomplete. There is thus the need for rigorous empirical work to offer a comprehensive understanding on how and to what extent gamification can generate positive psychological and behavioural outcomes that support value creation.

This thesis addresses this research gap, intent on extending our understanding on how gamification, as a tool, can be utilised as an engagement marketing effort to support value co-creation. By taking the case of physical activity as an instance of measurable behaviour change, this thesis examines how gamification can be utilised to create effective, engaging and meaningful experiences that facilitate positive outcomes.

This thesis thus investigates i) the psychological and behavioural outcomes evoked using different design choices of gamification; ii) the resulting effect of the emotional, cognitive and behavioural manifestations on the individuals' subjective well-being; and iii) the motivational affordances and underlying psychological processes through which gamified self-tracking experiences motivate users towards the desired behavioural change.

The study draws from the self-determination theory and gamification design frameworks to explore how different designs of gamification influence the users' motivation, behaviour change and well-being. Consistent with the critical realism philosophical stance, this thesis adopts a mixed methods research design involving three different research strategies.

First, a purposely designed randomised controlled field experiment examined how the choice of competitive, cooperative and hybrid (competitive-cooperative) gamification designs affects users' motivation, perceived usefulness of the experience and behavioural change. The data gathered included a panel dataset of step counts consisting of 2,240 observations over a four-week period, as well as self-reported data on the users' emotional and cognitive psychological responses from a sample of 80 participants. Second, a longitudinal survey study (amongst the same participants) examined how subjective well-being is influenced by experiences of self-tracking and gamification of physical activity. Self-reported data on happiness and life

satisfaction was gathered pre- and post-intervention. Third, a qualitative study helped gain a deeper insight into the gamification mechanisms and underlying psychological processes that fostered motivation towards physical activity behaviour. Focus groups and one-to-one interviews were conducted involving 58 participants.

Results show that gamification leads to a behavioural change in physical activity. All groups treated with gamification recorded an increase in physical activity. The hybrid design using an inter-team competition is considered as an optimal design that leads to the highest increase in step counts. While the use of gamification stimulates the desired behavioural change, the psychological responses to gamification (albeit positive) are not significantly different to a non-gamified self-tracking experience at the end of the intervention period.

Both gamified and non-gamified self-tracking experiences evoke similar positive psychological responses, yielding similar gains in well-being. Specifically, enjoyment and interest (hedonic benefit) enhance happiness levels, whereas perceived usefulness of the experience (utilitarian benefit) enhances life satisfaction levels. The change in physical activity behaviour however is not linked to the increase in well-being.

The key factors that foster motivation towards physical activity include personal goal setting, immediate and regular feedback, social comparison, competitive and cooperative elements, a sense of community spirit, gratifying rewards and enticing new experiences. By contrast, anonymity, lack of social interaction and weak group cohesion are perceived as limiting factors. The underlying emotions, feelings and cognitive processes that encourage users to engage in physical activity are compatible with the core constructs of the self-determination theory.

This thesis suggests that gamification can support a marketing strategy in the pursuit of value creation on three levels: i) behavioural, ii) experiential and iii) social. First, the results indicate that using gamification as a stimulus begets the desired behavioural change in the short-term. Second, at an experiential level, insights gained from the participants' subjective experiences suggest that gamification could influence motivation and enhance users' experience by providing a gratifying experience. This gratifying experience supports empowerment, autonomy, competence, progress, achievement and social relatedness. Empirical evidence from this thesis supports the theoretical prediction that experiences that foster intrinsic motivation and autonomous forms of extrinsic motivation enhance well-being. However, there is a need

to understand better how gamification can elicit stronger psychological responses. A critical reflection on the unintended consequences and ethical implications is also necessary. Third, insights emerging from this thesis suggest that social-oriented gamification features contribute to value co-creation by facilitating a sense of relatedness and connectedness with others.

In conclusion, this thesis extends our understanding of how gamification can be effectively used to contribute to the ultimate goal in the realm of marketing, that of supporting value co-creation.

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My gratitude goes to my family - my parents, my husband Christopher, and our daughter Matthea. Thank you for the endless support and patience. This thesis is dedicated to them.

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1 Introduction

1.1 Opening remarks

"Games, in the twenty-first century, will be a primary platform for enabling the future" – Jane McGonigal

Game design insights can teach us how to make our lives and the world better (McGonigal, 2011). Over the past decade, interest has grown rapidly amongst academics and practitioners about the opportunity of using game elements and game design principles in non-entertainment contexts to support various utilitarian goals and behaviours (Koivisto & Hamari, 2019b). This phenomenon, titled *gamification* attempts to induce experiences that are generally associated with games to support the users' motivation towards the targeted behaviour (Huotari & Hamari, 2011, 2012, 2017; Liu et al., 2017).

As a marketer, the prospect of harnessing the motivational and engaging power of game design elements to enhance the service offering and support value creation is intriguing. In consumer markets, gamification techniques are widely implemented in several domains, including health and fitness, education and crowdsourcing (Koivisto & Hamari, 2019b). From a service marketing perspective, gamification attempts to augment the value proposition of the product or service (Huotari & Hamari, 2012, 2017). In view of the expected outcomes of gamification, particularly the intended effect on customers' experience, engagement, motivation and behaviour change, gamification has been touted as a potential marketing strategy (Hamari et al., 2014; Harwood & Garry, 2015). As many firms seek to augment their service offering through gamification, there is the need to understand how gamification can promote and foster positive marketing outcomes (Bitrián et al., 2021).

Prior studies suggest that gamification could foster positive outcomes in terms of customer engagement (Bitrián et al., 2021; Hammedi et al., 2017, 2019; Harwood & Garry, 2015), brand engagement and equity (Xi & Hamari, 2019b), motivation (Landers et al., 2017), and business outcomes (Wolf et al., 2020). By contrast, other studies revealed potential drawbacks emerging from the application of gamification such as negative outcomes during the engagement process

(Leclercq et al., 2017). While some gamified experiences may enhance desired business outcomes, there is also the possibility of discordant effects (Wolf et al., 2020).

Rigorous empirical studies are justified and needed to provide a comprehensive understanding on how and to what extent gamification can generate positive outcomes that support the users' value creation (Hamari et al., 2014; Nacke & Deterding, 2017; Huotari & Hamari, 2017; Liu et al., 2017; Hofacker et al., 2016). This insight would help marketers and practitioners to design and develop optimised marketing strategies incorporating gamification to enhance the users' experience and support the overall users' value creation (Bitrián et al., 2021; Hofacker et al., 2016).

To address this gap, this thesis seeks to explore the potential of implementing gamification as an engagement marketing tool to extend our understanding on how and to what extent gamification affects the users' experiences, motivation and behavioural change. Positive impacts realised in these areas are especially relevant to the marketing discipline since these manifestations will contribute to value co-creation.

1.2 Defining gamification

The term *gamification* started to gain traction in late 2010 and since then, academic literature has grown exponentially. Originating from the Human-Computer Interaction domain, the first definition coined by Deterding et al. (2011) describes what constitutes a gamified system – '*the use of game design elements in non-game contexts'* (p. 1). Subsequent definitions incorporate the expected outcomes of gamification, focusing on the premise that gamification is intended to '*translate the engaging aspects of games into other domains of life to create positive experiences and drive desired behaviours'* (Deterding, 2019, p. 1).

Literature identifies three main elements involved in gamification: 1) the motivational affordances, 2) the psychological outcomes, and 3) the behavioural outcomes (Hamari et al., 2014; Huotari & Hamari, 2017). The gamification features implemented into a system or a service act as stimuli (motivational affordances) designed to provide a gameful experience, that can induce psychological outcomes, including enhanced users' motivation towards the intended behavioural outcome (Hamari et al., 2014; Huotari & Hamari, 2017). Similarly, Liu et al. (2017) emphasise that gamified systems should be designed to address two central goals,

namely the experiential (psychological) and instrumental (behavioural) outcomes. The instrumental outcomes refer to the intended behavioural outcomes for which gamification is intentionally designed. Experiential outcomes refer to various emotional and cognitive responses, such as enjoyment, usefulness, meaningfulness and satisfaction (Liu et al., 2017).

Given the ubiquity of gamification and its broad implementation in different fields in our everyday life, gamification has evolved to be far more than an Information Systems phenomenon (Koivisto & Hamari, 2019b). Huotari and Hamari (2012, 2017) positioned gamification theoretically on two domains of literature, namely Information Systems and Service Marketing. The authors define gamification as a process of enhancing a system or a service with game elements or game design principles to create a *'gameful experience'* that is intended to facilitate and '*support the users' overall value creation'* (Huotari & Hamari, 2012, p. 19). The gameful restructuring of activities through gamification is intended to enhance the experience of the service proposition or the organisation's core value offering (Huotari & Hamari, 2012, 2017) and '*create meaningful engagement for users'* (Liu et al., 2017, p. 1).

1.3 Distinguishing gamification from related concepts

While a conceptualisation of gamification from a multi-disciplinary background provides a holistic understanding of the underlying framework of this notion (Nacke & Deterding, 2017), a distinction from analogous yet independent conceptual developments is necessary. Related conceptual developments include *serious games*, *pervasive games*, and *persuasive technologies*. As opposed to *gamification* which integrates game design elements in a context that is not a game, *serious games* are designed as fully-fledged games that have a non-entertainment intended purpose, such as learning or practising a skill (Deterding et al., 2011; Michael & Chen, 2005). Exercise games, known as *exergames*, such as the Nintendo Wii Fit games are a type of serious games intended to provide a fun and engaging way of exercising (Göbel et al., 2010). While these games are intended to support various utilitarian goals through hedonic means, gamification has established itself as an independent conceptual development over the last decade (Deterding et al., 2011; Koivisto & Hamari, 2019b). By contrast, *pervasive games* involve games that are extended to the real world, such as location-based games and augmented reality games (Oppermann & Slussareff, 2016). Similarly, *gamification* and *persuasive technologies* share common ground with respect to using interactive technology

designed to influence users' attitudes and behaviour change (Fogg, 2002; Oinas-Kukkonen, 2010, 2013). However, gamification focuses on creating gameful experiences through the implementation of game design elements in non-game phenomena, while persuasive technologies focus more on persuasive communication strategies and social influence (Fogg, 2002; Huotari & Hamari, 2012). This demarcation sets the boundaries between gamification and related conceptual developments and establishes the positioning of this study within gamification research.

1.4 Positioning this thesis in marketing discipline

This thesis approaches gamification through a marketing lens. Implied in the conceptualisation of gamification (explained in Section 1.2), there are two core principles entrenched in the marketing discipline, namely *customer engagement marketing* (Harmeling et al., 2017) and *value co-creation* (Grönroos, 2011; Vargo & Lusch, 2004). Thus, this section explores the underlying connection between *gamification*, *customer engagement marketing* and *value co-creation* to serve as groundwork for the research approach adopted in this thesis.

1.4.1 Customer engagement marketing and gamification

Gamification shares a remarkable connection to the traits and characteristics of *customer engagement marketing* (Harmeling et al., 2017). *Customer engagement marketing* refers to the firm's strategic efforts to motivate, empower and encourage the customers' voluntary and active participation with the activities of the firm beyond the economic transaction (Harmeling et al., 2017). Likewise, gamification is intentionally designed and actively managed to guide, motivate, and empower users in ways which are in line with the desired behaviour (Huotari & Hamari, 2017). Akin to engagement marketing, gamification is intentionally incorporated within a real-world system to enrich the experience of the core offering (Harmeling et al., 2017; Huotari & Hamari, 2017). Both gamification and engagement marketing encourage voluntary participation and promote a customer transformation from a passive receiver to an active contributor in the value creation process (Harmeling et al., 2017). Firms gamify offerings that support interactions and resource exchanges to co-create value (Leclercq et al., 2017). These interactions occur in a network comprising of the service provider and the users (including user-to-user interactions), as is the case with engagement marketing efforts (Harmeling et al.,

2017; Leclercq et al., 2017). Finally, the desired outcome of creating *customer engagement* (Harmeling et al., 2017; Liu et al., 2017) to support *value creation* (Alexander & Jaakkola, 2015; Huotari & Hamari, 2012) is common for both gamification and engagement marketing.

Although marketing literature to date has been unable to offer a unifying conceptualisation of *customer engagement* (Bilro & Loureiro, 2020; Ng et al., 2020), scholars have shown consistency in seeing customer engagement as a multi-dimensional concept that is context-dependent and may vary over time (Brodie et al., 2011; Hollebeek et al., 2019; Vivek et al., 2012). Customer engagement can be construed as the psychological state (as per Brodie et al., 2011) and behavioural manifestations (as per Van Doorn et al., 2010) resulting from a motivated state. This occurs by virtue of the interactive customer experiences between the customers and the focal object, such as the firm, the brand, the service provider, and other stakeholders, including customers (Brodie et al., 2011; Hollebeek et al., 2019). Customer engagement is a multi-faceted construct comprising of emotional (affective), cognitive, and behavioural dimensions (Brodie et al., 2011). Recently, other scholars (Hollebeek et al., 2019; Vivek et al., 2012) suggested the addition of the social dimension to reflect the social commitments and benefits derived from an increasingly connected and networked environment in which these interactions occur. The manifestations that emanate from customer engagement support the value co-creation process (Alexander & Jaakkola, 2015).

1.4.2 Supporting value co-creation through gamification

Value and *value co-creation* lie at the core of modern marketing thinking that evolved over the past two decades. Value is '*an interactive relativistic preference experience*' (Holbrook, 1994, p. 27). *Value co-creation* is a process where actors (including firms, customers, or network members) interact and exchange their own resources to jointly co-create value (Grönroos, 2008; Leclercq et al., 2016). This conceptualisation is guided by the theoretical framework of the service-dominant logic, where the customer is a co-producer of value during service delivery (Vargo et al., 2008; Vargo & Lusch, 2004). Against this context, customers play an active role in value co-creation, and are the actors who evaluate and assign value to the firm's value proposition (Prahalad & Ramaswamy, 2004; Vargo & Lusch, 2004). Based on the value-in-use concept, the overall value created through gamification is determined by the users' interactive experience with the gamified system (Huotari & Hamari, 2012, 2017), and is

manifested in various psychological and behavioural outcomes (Koivisto & Hamari, 2019b). However, designing a gamified system or an engagement marketing initiative does not guarantee *customer engagement* or *value co-creation* (Huotari & Hamari, 2012, 2017).

Previous investigations into virtual customer environments suggest that the customers' voluntary participation and engagement in value co-creation activities is motivated by the anticipated benefits derived from engaging in such activities (Nambisan & Baron, 2009). Benefits include those of hedonic, cognitive, personal integrative, and social integrative nature (Nambisan & Baron, 2009). The observable manifestations of *hedonic benefits* encompass feelings of pleasure, affect and enjoyment; *cognitive benefits* encompass the utilitarian and functional benefits derived from information acquisition and feedback; *personal integrative benefits* relate to personal achievement, gains in reputation or status, self-enhancement and a sense of self-efficacy; and *social integrative benefits* derived from the relational connections with others are manifested in a sense of belongingness or social identity (Nambisan & Baron, 2009).

Drawing on the theoretical concepts and foundations from the domain of marketing discussed in this Chapter, this thesis sets out a comprehensive investigation on the extent of the use of gamification as an engagement marketing tool fostering positive outcomes that support value co-creation. To this end, this thesis considers different manifestations evoked through gamification that could influence value co-creation, including the effect of gamification on the users' experiences, motivation and behaviour change.

1.5 Field of application and research problem

Physical activity is chosen as the context of this thesis since the effect of gamification on behaviour change can be tracked and measured objectively using wearable activity trackers, rather than relying on subjective measures such as participants' recall.

The use of gamification has become extremely popular in fitness mobile applications to promote and support positive health behaviours, primarily targeted at increasing physical activity (Cotton & Patel, 2019; Lister et al., 2014; Schmidt-Kraepelin et al., 2018). Surprisingly, despite the increased application of gamification in fitness applications in industry practice, scientific empirical evidence validating the promising favourable claims on

the effects of gamification in this context is limited (Koivisto & Hamari, 2019a). Empirical evidence that confirms the promised outcomes on users' motivation, psychological state and actual behaviour change is crucial (Koivisto & Hamari, 2019a). In the context of physical activity, behaviour change can be tracked and measured objectively through the use of wearable activity trackers that incorporate sensor-based technologies, rather than relying on subjective measures.

If the use gamification stimulates the desired favourable outcomes, it could have wide-ranging benefits for society in general. The risks associated with insufficient physical activity are so high that insufficient physical activity is being considered as a silent pandemic causing more than five million deaths yearly (Lee et al., 2012; WHO, 2018a). Globally, one in every four adults do not reach the recommended levels of physical activity proposed by the World Health Organisation (Guthold et al., 2018; WHO, 2018a). This study is conducted in Malta, a country with a high prevalence rate of insufficient physical activity and high rates of overweight and obese people (WHO, 2018b, 2022). Recent statistics published by the Eurobarometer indicate that 68% of Maltese respondents never or seldom engage in physical exercise (European Commission, 2022). Moreover, progress to achieve the targets set by the World Health Organisation to reduce insufficient physical activity has been slow (WHO, 2018a). To this end, Malta's smart specialisation strategy (MCST, 2021) identifies that there is scope for further exploration for research and innovation potential in health and well-being, as well as digital technologies. Encouraging a more active lifestyle offers great potential to prevent a broad range of health issues and non-communicable diseases (Lee et al., 2012; WHO, 2020), as well as improving people's quality of life and well-being (Hyde et al., 2013; Penedo & Dahn, 2005).

Existing empirical evidence indicates that the effect of gamification on physical activity is predominantly positively oriented (Johnson et al., 2016; Koivisto & Hamari, 2019a; Mazéas et al., 2022). However, there are several limitations that not only prevent us from a comprehensive understanding on the effect of gamifying physical activity but lead us to question whether these favourable effects are actually being realised through gamification (Mazéas et al., 2022). These limitations emerge from three observations explained in the forthcoming paragraphs.

First, rigorous empirical studies on the effect of gamification of physical activity are limited (Johnson et al., 2016; Koivisto & Hamari, 2019a; Mazéas et al., 2022). Moreover, there is

significant heterogeneity between existing studies in terms of the studies' quality and study designs (Mazéas et al., 2022). The inability to conclude that the observed positive behavioural change is led by the implementation of gamification is a key limitation (Mazéas et al., 2022). Hence, literature would benefit from rigorous field experimental studies that include randomisation and controlled conditions to investigate the effect of gamification (Johnson et al., 2016; Koivisto & Hamari, 2019a; Mazéas et al., 2022; Nacke & Deterding, 2017).

Second, there is limited evidence on what type of gamification design can create effective, engaging, and meaningful experiences that facilitates the desired behavioural change (Liu et al., 2017; Nacke & Deterding, 2017; Rapp et al., 2019). Previous research has predominantly examined the effect of gamified applications or systems as a whole (Koivisto & Hamari, 2019b). There is evidence that different gamification designs can lead to different results in terms of users' motivation and behaviour (Chen & Pu, 2014; Morschheuser et al., 2019; Patel et al., 2019). However, results are context dependent, and thus the same gamification designs may lead to different outcomes in different contexts (Koivisto & Hamari, 2019b; Morschheuser et al., 2019). The lack of comparative studies investigating different gamification designs prevents us from knowing which type of gamification design is most optimal for physical activity. Thus, it is recommended that future studies involve two or more intervention groups to isolate the effect of different gamification elements or designs (Mazéas et al., 2022).

Third, gamification research lacks studies that investigate the effect of gamified interventions holistically, relating to psychological and behavioural outcomes in the field (Mazéas et al., 2022; Nacke & Deterding, 2017). Most studies consider only singular outcomes resulting from gamification, and thus fail to provide a comprehensive outlook of how gamification mechanisms work (Mazéas et al., 2022; Nacke & Deterding, 2017). A combination of measures and research methods would be useful to capture the many facets of how gamification can support users' engagement and value co-creation (Leclercq et al., 2017).

In synthesis, to extend our understanding of how gamification can support value co-creation, empirical studies involving randomised, controlled conditions that shed light on both psychological and behavioural outcomes of gamification are encouraged (Koivisto & Hamari, 2019a; Mazéas et al., 2022). Understanding which gamification design or individual game elements produce positive effects, and under which circumstances or contexts are these

favourable effects realised is thus important. Equally the grasp of how, and to what extent, is gamification able to generate positive outcomes that support the users' overall value creation is a valid quest for academics and practitioners alike (Hamari et al., 2014; Koivisto & Hamari, 2019b; Liu et al., 2017; Nacke & Deterding, 2017; Rapp et al., 2019; Schmidt-Kraepelin et al., 2020).

1.6 Aims, objectives and research questions

In view of the aforementioned research gaps and limitations, this thesis set out to advance our knowledge and understanding on how gamification can be utilised to create effective, engaging and meaningful experiences that facilitate the desired psychological and behavioural outcomes to support the users' overall value creation in the context of physical activity.

Specifically, this thesis investigates three research questions:

Research Question 1: How does gamification of physical activity affect psychological and behavioural outcomes?

First, this study investigates the effect of gamification on the intended behavioural change (physical activity) and the users' psychological (emotional and cognitive) responses. Specifically, this study investigates:

i. whether the use of gamification facilitates the desired behavioural change (increase in step counts);
ii. how the choice of gamification design affects the behavioural change in physical activity; and
iii. how the use of gamification influences the users' intrinsic motivation and perceived usefulness.

A randomised controlled field experiment was purposely designed to investigate the effect of gamification of physical activity since this is the most rigorous form of research method in order to isolate and estimate the effect of a treatment (Twisk et al., 2018). Consistent with established classification frameworks on gamification design identified in literature (Liu et al., 2013; Morschheuser et al., 2017), this study examines three different designs of gamification commonly used in fitness applications, namely, competitive, cooperative, and hybrid

(competitive-cooperative) designs. Physical activity is tracked and measured objectively through the use of wearable activity trackers that incorporate sensor-based technologies. The data gathered includes a longitudinal panel dataset of step counts to investigate the causal effect of gamification on physical activity, as well as self-reported data to examine the effect of gamification on psychological outcomes, in terms of *perceived enjoyment and interest*, and *perceived usefulness* of the experience.

Research Question 2: Do experiences of gamification and self-tracking of physical activity create positive emotional, cognitive, and behavioural responses that yield enhanced well-being?

Second, this study investigates whether experiences of gamification and self-tracking of physical activity create positive emotional, cognitive, and behavioural responses that yield enhanced well-being. Literature suggests that physical activity trackers and gamification can have beneficial effects on users' well-being (Johnson et al., 2016; Schmidt-Kraepelin et al., 2020), however the effectiveness of these behavioural interventions has not been sufficiently examined (Hermsen et al., 2016; Johnson et al., 2016; Rapp et al., 2019; Stiglbauer et al., 2019).

Specifically, this study investigates whether:

i. the use of gamification enhances the effect on well-being (relative to a non-gamified self-tracking experience);
ii. the users' cognitive response to the intervention based on the utilitarian benefit of the experience (perceived usefulness) enhances well-being gain;
iii. the users' emotional response to the intervention based on the hedonic benefit (enjoyment and interest) of the experience enhances well-being gain; and
iv. the users' behavioural response to the intervention (change in physical activity) enhances the well-being gain.

To answer these objectives, this study utilises data from a longitudinal survey study measuring well-being (*life satisfaction* and *happiness*) before and after an experience of self-tracking, alone and in conjunction with gamification. The individuals' emotional and cognitive psychological responses, as well as the individuals' behavioural change in physical activity are measured to examine the resultant effect on well-being.

Research Question 3: How do gamified self-tracking experiences foster motivation towards physical activity?

Third, this study explores the complexity of how gamified self-tracking can foster motivation towards physical activity. Consistent with a critical realist stance (Zachariadis et al., 2013), we may not be able to observe the underlying processes and mechanisms that led to the users' emotional, cognitive, and behavioural responses through quantitative measures. Hence, following the field experiment on gamification of physical activity, a qualitative study identifies and explores the underlying processes and conditions that encourage users to engage in physical activity. This study extends our understanding of the gamification mechanisms and the underlying psychological processes that nurture the users' motivation towards physical activity. This knowledge helps us understand better how gamification can be utilised to create engaging gamified experiences that support physical activity and enhance the users' value creation.

1.7 Thesis outline

This chapter laid the foundations for this thesis by exploring the promising avenue of employing gamification as part of an engagement marketing strategy to support value co-creation. This thesis seeks to extend our knowledge on how and to what extent gamification can be utilised to create engaging and meaningful experiences that facilitate positive psychological and behavioural outcomes in the context of physical activity. Specifically, the thesis examines the effect of gamification on the users' experiences, motivation and behaviour change. Positive impacts realised in these areas are especially relevant to the marketing discipline since these manifestations will contribute to value co-creation. The research problem, aims, objectives and research questions for this thesis have been identified in this Chapter. On these foundations, the thesis follows the research trajectory presented in Figure 1.

Since gamification is intended to affect the users' motivation towards the desired behaviour, research into the design and effectiveness of gamification is commonly guided by theoretical frameworks related to motivation and behaviour change (Seaborn & Fels, 2015). The theoretical framework that guides this thesis (explained in the forthcoming chapter) is the Self-Determination Theory (Ryan & Deci, 2000b). The Self-Determination Theory presents a broad framework for understanding motivation and identifies fundamental psychological needs that

when satisfied contribute to self-motivation and enhanced well-being (Ryan & Deci, 2000b). Chapter 2 explores how different gamified designs (competition, cooperation and hybrid) identified in gamification literature (Liu et al., 2013; Morschheuser et al., 2017) support the individuals' experience of autonomy, competence and relatedness, thus influencing the individuals' motivation towards the desired behaviour and the individuals' well-being. Literature related to physical activity (as the field of application for this study) and well-being is also presented in Chapter 2. Following a thorough review of the current state of empirical research in this field and the existing research gaps, the research questions for this thesis are specified in further detail together with the hypotheses.

Chapter 3 presents the research philosophical approach and research methodology for this thesis. Consistent with the critical realism philosophical stance, this thesis adopts a mixed methods research design involving three different research strategies, namely i) a randomised controlled experiment to investigate the psychological and behavioural outcomes; ii) a longitudinal survey study to investigate how subjective well-being is influenced by experiences of gamification and self-tracking of physical activity; and iii) a qualitative study to gain a deeper insight into the gamification mechanisms and underlying psychological processes that foster motivation towards the desired behaviour. Details pertaining to these research strategies including the data collection procedure and data analysis methods are explained, followed by ethical considerations, methodological strengths and limitations.

The empirical findings are presented in Chapter 4, followed by a discussion on the findings in relation to previous empirical works and the implications for research and industry practice in Chapter 5. The implications of using gamification to foster positive marketing outcomes in terms of the users' experience, motivation and behaviour change will be discussed together with potential ethical issues related to the use of gamification in this field. Finally, Chapter 6 concludes this thesis by presenting the conclusions for the research questions, discussing the contributions to theory and industry practice, the limitations of this thesis and potential areas for future research.

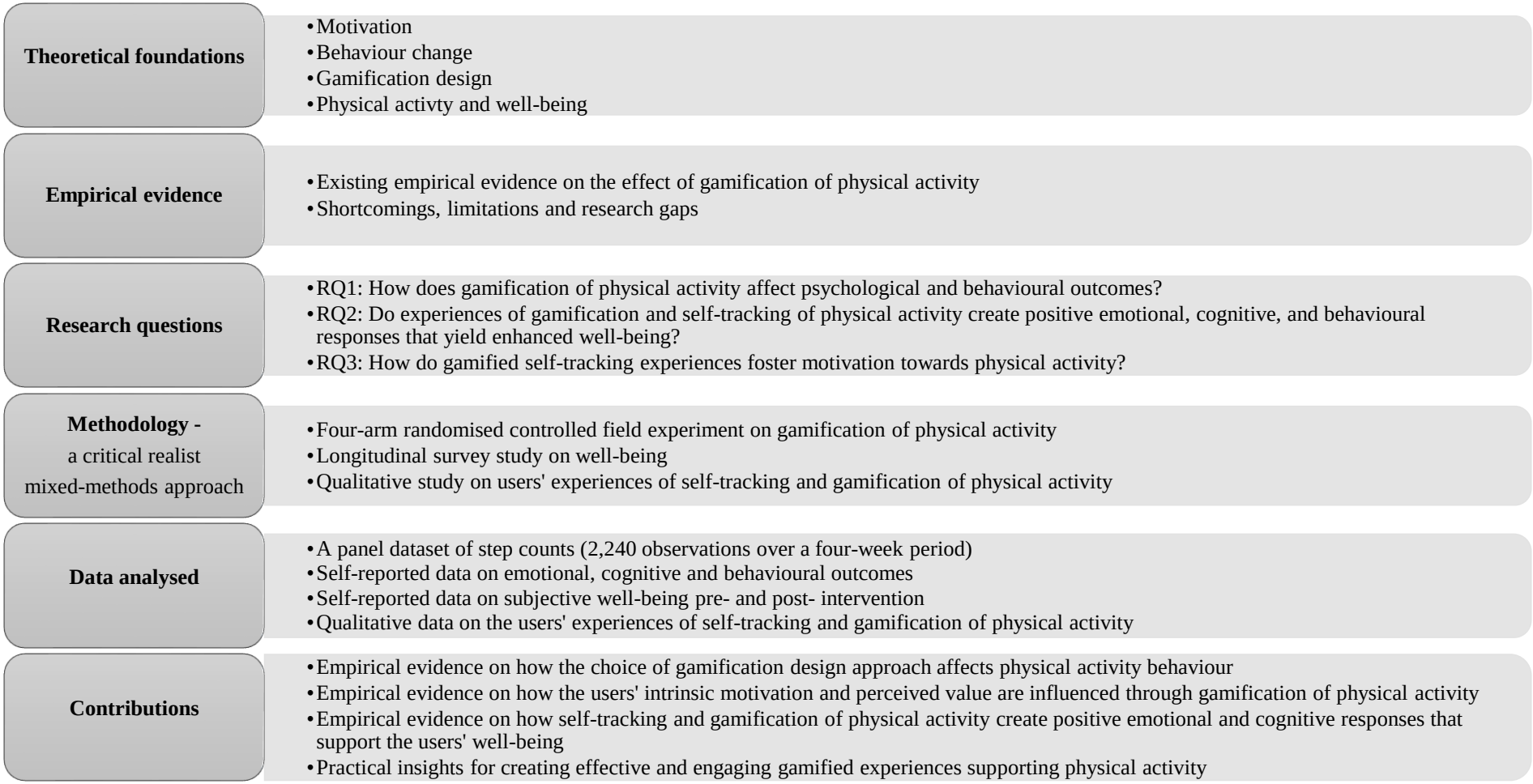

Figure 1: Research trajectory

2 Theoretical Foundations and Empirical Evidence

2.1 Introduction

Due to the eclectic nature of gamification, the theoretical and conceptual foundations related to this phenomenon emerge from information systems, games, and social science domains (Huotari & Hamari, 2017; Nacke & Deterding, 2017). The theoretical foundations presented in this chapter draw insights from psychological theories related to motivation (Section 2.2.1) and behaviour change (Section 2.2.2). Different designs can influence individuals' motivation and behaviour in several ways (Johnson & Johnson, 1989; Tauer & Harackiewicz, 2004). Hence, Section 2.2.3 distinguishes between different types of gamification designs using established gamification design research frameworks (Liu et al., 2013; Morschheuser et al., 2017).

The literature related to the field of application chosen for this thesis (physical activity) is presented in Section 2.3. This section discusses the determinants, facilitators and barriers of physical activity and the association between physical activity and well-being. Subsequently this section explains the theoretical underpinnings of how gamification and self-tracking of physical activity can enhance well-being. Section 2.4 synthesises existing empirical evidence on the use and effect of gamification of physical activity. The shortcomings, limitations and research gaps are explained in Section 2.5, followed by the research questions together and the specific hypotheses set out for this thesis in Section 2.6.

2.2 Gamification design for motivation and behaviour change

2.2.1 Motivation

Harnessing on the motivational and engaging power of game design characteristics, gamification has the potential to promote motivation towards various utilitarian goals and foster behaviour change (Hamari & Koivisto, 2015a; Seaborn & Fels, 2015; Walz & Deterding, 2015). The motivation to engage in an activity or a task can be categorised into intrinsic motivation and extrinsic motivation (Ryan & Deci, 2000a). People are intrinsically motivated when they do an activity for its inherent satisfaction, interest, and enjoyment. By contrast, extrinsic motivation relates to behaviour that is driven by external outcomes, rewards, pressures or fears (Ryan & Deci, 2000a). A widely researched theoretical framework on human

motivation that draws on the conceptualisation of intrinsic and extrinsic motivation is the self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2000a).

The self-determination theory differentiates between autonomous and controlled forms of motivation (Deci & Ryan, 2008). Autonomous (or self-determined motivation) includes not only intrinsic sources of motivation, but also some types of extrinsic motivation where the behaviour is endorsed due to the perceived value of the activity (identified regulation) and congruence with the individual's personal values and needs (integrated regulation) (Deci & Ryan, 2008). On the other hand, controlled motivation emanates from compliance due to fear of punishments, failure, pressure or ego-threats (Deci & Ryan, 2008). Literature (Biddle & Mutrie, 2007) claims that motivation for physical activity is stronger if it involves greater autonomy, choice and self-determination, rather than externally controlled forms of motivation.

The self-determination theory identifies three innate psychological needs that support self-motivation, namely the need for competence, autonomy, and relatedness (Ryan & Deci, 2000b). First, competence refers to the need for challenge, feelings of ability, mastery and achievement of the task at hand (Rigby, 2014; Ryan & Deci, 2000b). Providing optimal challenges and positive feedback enhances perceived competence (Ryan et al., 2006; Ryan & Deci, 2000b). Second, autonomy refers to the users' freedom of choice in deciding which actions to undertake (Ryan & Deci, 2000b; Vansteenkiste et al., 2010). Providing opportunities for choice and informational feedback enhances autonomy. Conversely, environments that diminish the sense of control on one's actions undermines autonomy and intrinsic motivation (Ryan et al., 2006). Lastly, relatedness refers to the sense of belonging and feelings of connectedness with others, which is promoted through environments characterised by a sense of mutual respect, support, and security (Rigby, 2014; Ryan & Deci, 2000b; Vansteenkiste et al., 2004). Satisfying these three basic psychological needs promotes self-motivation and enhances the individuals' well-being and health (Ryan & Deci, 2000b). By contrast, motivation and well-being are hampered when these innate psychological needs are not met (Ryan & Deci, 2000b).

2.2.2 Behaviour change

Behaviour change is a commonly recognised as a desired outcome of gamification being driven by intrinsic and extrinsic motivations (Johnson et al., 2016; Schmidt-Kraepelin et al., 2020; Seaborn & Fels, 2015). There are several validated theoretical frameworks in literature that explore behaviour change including the transtheoretical model of health behaviour change (Prochaska & Velicer, 1997), the theory of planned behaviour (Ajzen, 1991), and the social cognitive theory (Bandura, 1997).

The transtheoretical model of health behaviour change suggests that modifying a behaviour typically requires an individual to move through a gradual progression of a series of stages, rather than a singular change from inactive to active (Prochaska & Velicer, 1997). Also known as the 'stages of change model', this theoretical framework identifies a six stage-based process (precontemplation, contemplation, preparation, action, maintenance, and termination) that people go through when modifying a behaviour (Prochaska & Velicer, 1997). Literature suggests that the way people respond to a behavioural change intervention and the effect the intervention will have varies depending on the individual's readiness to behaviour change (Lin et al., 2006; Reynolds et al., 2013) described in terms of the stages of change in the transtheoretical model.

Research about encouraging physical activity using interactive game elements suggests that individuals in the pre-contemplation stage are the least likely to achieve a significant change in physical activity compared to those in later stages within the transtheoretical model (Lin et al., 2006). A shift in the attitude of individuals in the pre-contemplation stage may be required before demonstrating an observable behavioural change (Lin et al., 2006). Interventions that involve self-monitoring, goal setting, and self-reward can increase participation amongst those people who do intend to exercise (Lin et al., 2006; Martin et al., 1984). However, interventions may not lead to the desired behavioural change in the case of individuals who are still not ready or willing to change their behaviour (pre-contemplation stage).

The theory of planned behaviour proposed by Ajzen (1991) explains the factors that predict and influence an individual's decision to engage in a specific behaviour. This theoretical framework posits that the proximal determinant of behaviour is the *intention* to engage in the desired behaviour (Ajzen, 1991). The behavioural intention is an indicator of the motivation

and willingness people plan to exert towards the target behaviour. In turn, intention is influenced by the attitude towards the behaviour of interest, subjective norms, and perceived behavioural control (Ajzen, 1991). On the basis of the theory of planned behaviour, individuals are more likely to engage in the desired behaviour, such as physical activity if they are: a) motivated to do so (*behavioural intention*); b) they have a positive outlook towards participating in physical activity (*attitude*); c) other people with whom they relate think they should engage in physical activity (*subjective norms*); and d) they feel able to engage in physical activity if they want to (*perceived behavioural control*). Studies find that the constructs of the theory of planned behaviour are significant predictors of the current exercise stage in the transtheoretical model (Courneya et al., 1998).

The perceived behavioural control (one of the constructs of the theory of planned behaviour) is conceptually similar to *self-efficacy* from the social cognitive theory (Bandura, 1997). According to the social cognitive theory proposed by Bandura (1997), an individual's behaviour is affected by personal factors, environmental factors, and attributes of the behaviour itself. Individuals learn to adopt new behaviours by observing others as well as through the consequences (positive and negative reinforcement) to their own behaviour (Bandura, 1997). A large body of literature supports the validity of these theoretical frameworks in the areas of health, physical activity and exercise behaviour (Armitage, 2005; Armitage & Conner, 2001; Courneya et al., 1998; Hagger et al., 2002; Hagger & Chatzisarantis, 2009; Hardeman et al., 2002).

The theoretical models discussed in this chapter help us to understand how and why people are motivated or demotivated to engage in a specific behaviour (in this case physical activity) and the factors influencing the initiation and maintenance of the desired behaviour (Biddle & Mutrie, 2007). There is further scope for intervention studies adopting principles based on these theoretical frameworks and qualitative studies to further our knowledge into how behavioural interventions can foster motivation towards physical activity (Hagger & Chatzisarantis, 2008; Ryan & Deci, 2020). Integrating these theoretical models can provide more comprehensive explanations of motivation for physical activity (Hagger & Chatzisarantis, 2008). Behavioural interventions involving competitive and cooperative elements can influence individuals' motivation and behaviour (Johnson & Johnson, 1989; Tauer & Harackiewicz, 2004). Thus, the forthcoming section explains how different gamification designs could provide opportunities

to support the innate psychological needs fostering motivation towards the desired behavioural change.

2.2.3 Gamification design

The rich variety of game elements and mechanics that could be implemented in gamified systems offer endless possibilities for gamification design (Morschheuser et al., 2017). Recent studies identified that the most common game elements used in health and fitness applications include goals, social influences, challenges, collaboration, and competition (Cotton & Patel, 2019). Similarly, a recent systematic review conducted by Neupane et al. (2021) identified that many gamified fitness tracker applications use a combination of game elements that include social influence, competition, and challenges. Moreover, sensor-captured data through wearable devices, such as step counts is commonly integrated within gamified fitness tracker applications either as a mechanism to trigger reward, or as a virtual currency which could be traded for in-game or real-life rewards (Neupane et al., 2021).

Gamified fitness applications, such as Nike+ Run Club, MapMyRun, Fitbit, Strava and Pacer, 'connect' individuals to a community of users who are also performing similar activities. It is common for the design of gamified applications to include a social setting and a strong presence of social features (Hamari & Koivisto, 2013; Neupane et al., 2020). Earlier studies suggested that social factors are determinants of the attitude and use of gamified fitness applications (Hamari & Koivisto, 2013, 2015b). The use of gamification and being part of a group or team (i.e. a social setting) are determining factors that positively influence the users' adherence to physical activity applications (Yang et al., 2020).

Drawing on the social interdependence theory (Johnson, 2003; Johnson & Johnson, 2005), emergent research frameworks distinguish between different types of gamification designs (Liu et al., 2013; Morschheuser et al., 2017). Gamification designs can be classified as i) individualistic, ii) cooperative, iii) competitive, or iv) cooperative-competitive, also referred to as hybrid, inter-team competition, or coopetition (Liu et al., 2013; Morschheuser et al., 2017). The choice of game elements and features utilised determines the nature of the gamified system (Morschheuser et al., 2017).

An *individualistic gamified design* includes game elements such as private badges or levels to motivate users to achieve their individual personal goals, without causing interdependence among individuals (Morschheuser et al., 2017). The other three types of gamified designs involve a social-oriented goal setting mechanism. A *cooperative gamified design* is based on a positive goal interdependence where users collaborate to achieve a shared goal through cooperative game elements, such as shared puzzles or team challenges (Morschheuser et al., 2017). By contrast, a *competitive gamified design* invokes a negative goal interdependence where users compete against others to achieve a goal through gamification features, such as competitions, leaderboard, and public rankings (Morschheuser et al., 2017). The combination of competition and cooperation gamification features results in a *cooperative-competitive gamified design*, such as the case of an inter-team competition, where individuals are cooperating with their team players to achieve a shared goal, whilst also competing with other teams (Liu et al., 2013; Morschheuser et al., 2017; Tauer & Harackiewicz, 2004).

Research shows that interpersonal social contexts lead to higher levels of performance compared to individualistic contexts (Johnson & Johnson, 1989; Stanne et al., 1999). An interpersonal social setting presents different gamification design opportunities where several behavioural processes come into play. In a social setting, users are exposed to various forms of social influence, social comparison, and social support opportunities. Social influence refers to the process where individuals' attitudes, beliefs and behaviours are altered due the presence or actions of other people in their social environment (Kelman, 1958). The behaviour of an individual could be influenced and guided by the norms of the reference group both through descriptive and injunctive subjective norms (Ajzen, 1991; Cialdini & Trost, 1998). Social comparison refers to the process by which people compare their performance with others (Buunk & Gibbons, 2007). Through upwards and downward social comparison, individuals self-evaluate their standing relative to others in the group with the intention to improve themselves and / or enhance their self-esteem (Festinger, 1954). Social comparison is commonly implemented in gamified applications through leaderboard rankings which display the users' performance relative to others, thus stimulating competition among the users (Schmidt-Kraepelin et al., 2018; Wu et al., 2015).

2.2.3.1 Competitive designs

Competitive environments can increase the individuals' desire to do well and provide a sense of challenge and excitement (Epstein & Harackiewicz, 1992; Tauer & Harackiewicz, 2004). As a result, individuals become more engaged and involved in the task, thereby fostering motivation (Tauer & Harackiewicz, 2004). Literature suggests that the strive for success is positively associated with performance and personal growth (Wolf et al., 2021). Competitions have the potential to satisfy the innate psychological need for competence providing a sense of achievement and satisfaction (Tauer & Harackiewicz, 2004). These effects are consistent with the self-determination constructs that promote motivation and enhance wellbeing (Deci et al., 1999). Studies show that positive feedback during the competition enhances intrinsic motivation (Reeve & Deci, 1996; Tauer & Harackiewicz, 2004). However, as argued by Santhanam et al. (2016) not all competitions are equally motivating. Competitive environments could also be demotivating for low achievers or when the individuals' level of skill is unbalanced (Epstein & Harackiewicz, 1992; Liu et al., 2013; Santhanam et al., 2016; Shameli et al., 2017). Focusing on winning rather than the task itself undermines intrinsic motivation (Deci et al., 1981). The fear of failure could negatively impact users' engagement and life satisfaction (Wolf et al., 2021).

2.2.3.2 Cooperative designs

Cooperative designs also provide opportunities to enhance motivation and task performance (Tauer & Harackiewicz, 2004). The concept of a group provides a nurturing environment for social support and relatedness through which other needs can be better met (Martin & Dowson, 2009). Being part of a group working towards a shared goal begets a sense of social relatedness, which has been identified as one of the constructs promoting self-determined motivation (Ryan & Deci, 2000b; Tauer & Harackiewicz, 2004). Cooperative environments could provide opportunities for social support that enhance motivation and promotes the desired behaviour (Ryan & Deci, 2000b). Positive feedback on achieving the shared goal evokes feelings of competence and mastery, and in turn, enhance motivation and wellbeing (Ryan et al., 2006; Ryan & Deci, 2000b; Tauer & Harackiewicz, 2004). However, cooperation could also undermine motivation when they feel a loss of autonomy, if joint commitment from the group members is missing, if participants fail to achieve the shared goal or if individuals perceive the

shared goal as externally controlling (Johnson & Johnson, 1989; Tauer & Harackiewicz, 2004). In turn, such cases would also hamper the individuals' wellbeing (Ryan & Deci, 2000b).

2.2.3.3 Hybrid designs (competitive-cooperative)

The competitive-cooperative design provides opportunities that enable individuals to foster positive relations and support among their team members, while getting involved into the competitive spirit to perform better than other teams (Liu et al., 2013; Tauer & Harackiewicz, 2004). Taken together, the feelings of relatedness, social support, as well as competence give rise to motivation and enhanced wellbeing (Ryan & Deci, 2000b). The hybrid design of competition-cooperation creates an environment which supports the individualism promoted through competition, as well as the collectivism and interdependence that exists in cooperative designs. Studies show that the simultaneous occurrence of competition and collaboration, such as the case of an inter-team competition led to even greater benefits than pure competition or pure collaboration in sports (Tauer & Harackiewicz, 2004), and also in other gamification domains such as crowdsourcing (Morschheuser et al., 2019). Thus, hypothesis 2 posits that the use of a hybrid gamified design will generate the strongest positive effect on behaviour change.

2.3 Physical activity and well-being

2.3.1 Correlates of physical activity and well-being

Physical activity behaviour correlates with a diversity of factors including individual traits, psychological, social, environmental and policy factors (Biddle & Mutrie, 2007; Eyler, 2003). Evidence suggests positive associations between physical activity and the male gender, individuals who have higher levels of education and socio-economic status, and individuals with prior involvement in physical activity and sport (Biddle & Mutrie, 2007; Eyler, 2003). By contrast, negative associations with weight and age have been reported (Trost et al., 2002). Sadly, as individuals grow older, their physical activity and well-being levels start to decline when compared to childhood levels and remain relatively stable at low levels during adulthood (Biddle & Mutrie, 2007; Hyde et al., 2013). Whilst physical activity remains low throughout a person's life cycle following the decline from childhood levels, there tends to be a positive shift in the trajectory of well-being during the older age groups (close to retirement years), and then a gradual decline in the older years (Blanchflower & Oswald, 2008; Hyde et al., 2013).

Psychological variables (identified in the theoretical models discussed in Section 2.2) play an important role in the adoption and maintenance of physical activity (Biddle & Mutrie, 2007). These variables include attitudes and beliefs towards physical activity, behavioural intention, behavioural control or self-efficacy, motivation, and perceived benefits (Biddle & Mutrie, 2007; Eyler, 2003). Feelings related to well-being and enjoyment of the activity are also important in the maintenance of physical activity (Dishman et al., 1985).

Social factors such as family and peers' influences also cause a significant impact on the adoption and maintenance of physical activity behaviour (Biddle & Mutrie, 2007). Social support is positively associated with physical activity behaviour (Biddle & Mutrie, 2007). Physical activity behaviour is also influenced by environmental and policy factors such as convenience of facilities conducive to physical exercise, and perceptions of traffic (Biddle & Mutrie, 2007; Cortis et al., 2017; Dishman et al., 1985).

There is a growing body of literature suggesting a positive correlation between physical activity and well-being (Iwon et al., 2021; Penedo & Dahn, 2005; Wiese et al., 2018). Well-being is defined as *'a person's cognitive and affective evaluations of his or her life'* (Diener et al., 2009, p. 187). Evidence suggests that leisure-time physical activity is correlated with positive affect, life satisfaction (Wiese et al., 2018), and happiness (Argyle, 2001; Zhang & Chen, 2019). The magnitude of this association is small (Wiese et al., 2018). Apart from the individual's health (physical and mental), subjective well-being is also affected by the individual's lifecycle stage, income and employment, education, relationship status, religious participation, socialisation, environment quality and cultural participation (Blanchflower & Oswald, 2008; Briguglio, 2019).

A lack of physical activity may emerge in response to several barriers, including lack of time, lack of willpower, health-related problems, lack of energy and motivation, and lack of self-regulatory skills (Biddle & Mutrie, 2007; Dishman et al., 1985). Lack of access to facilities or places to exercise in the community have also been reported as a barrier to physical activity (Eyler, 2003), as well as a lack of awareness of the individual's level of physical activity on a daily basis. Due to optimistic bias, there is the tendency that people mistakenly believe that they do more physical activity than they actually do (UK Department of Health, 2004). To address these challenges, motivational design technologies including self-tracking and

gamification are extensively being used to encourage a positive behaviour change in physical activity, health, and well-being.

2.3.2 Theoretical explanation for the proposed benefits on well-being

Motivational design technologies that promote physical activity can also enhance well-being outcomes (Abdin et al., 2018; Penedo & Dahn, 2005). This premise is based on the underlying emotional, cognitive, and behavioural processes that these interventions can bring about. For instance, consistent with the self-determination theory (Ryan & Deci, 2000b) activities that provide an intrinsically motivating experience, or that are well-internalised (due to the perceived value of the activity or congruence with one's values and needs) are associated with enhanced subjective well-being (Ryan & Deci, 2000b).

Studies examining whether an activity is intrinsically motivating commonly assess the individuals' subjective experience in terms of *enjoyment and interest* (Ryan, 1982; Wu & Lu, 2013). Enjoyment and interest reflect the individual's emotional psychological response to the intervention based on the hedonic benefit derived from the experience. By contrast, *perceived usefulness* reflects the users' cognitive response to the intervention based on the utilitarian benefit of the experience. Perceived usefulness facilitates internalisation and integration of extrinsically motivated behaviours (Deci et al., 1994; Ryan & Deci, 2000b) and is a widely used measure in studies examining internalisation of extrinsically motivated behaviours (Wu & Lu, 2013). The advantages of internalisation include more autonomous and volitional commitment towards the desired behaviour and enhanced subjective well-being (Ryan & Deci, 2000b).

Self-tracking technologies (also referred to as *quantified self*) (Lupton, 2016) enable people to collect data about themselves. Physical activity trackers help people realise their level of physical activity or rather inactivity. The provision of personal informatics data received through the use of activity trackers initiates a process of self-reflection and evaluation (Li et al., 2010; Rapp et al., 2018). This process brings about behaviour change opportunities for self-improvement (Bandura, 1991; Kersten-van Dijk et al., 2017). The desirable behaviours are facilitated through goal setting, reminders, and goal achievement (Kersten-van Dijk et al., 2017; Munson & Consolvo, 2012). Empirical evidence shows that the data management, social interaction, feedback, reminders, and goal management features incorporated in mobile fitness

technologies are positively associated with physical health and psychological well-being (Suh & Li, 2022). Self-tracking experiences facilitate informational feedback that simultaneously also brings about hedonic and affective responses (Hassan et al., 2019, 2020). The informational feedback and benefits provided by self-tracking experiences help users realise the utilitarian value and perceived usefulness of the activity, which in turn acts as a motivational tool (Hassan et al., 2019; Ryan & Deci, 2020). When individuals recognise and identify the perceived value of an activity, they internalise and integrate the desired behaviour, yielding self-motivation and enhanced subjective well-being (Ryan & Deci, 2000b).

Gamification is commonly integrated with self-tracking technologies to enhance the intervention's intended effects and promote engagement (Cheng et al., 2019; Johnson et al., 2016). The intrinsically motivating positive experience that gamification is intended to provide supports the initiation, reinforcement, and maintenance of healthy behaviours (Johnson et al., 2016). Gamification serves a dual-purpose, users can derive both hedonic and utilitarian benefits (Liu et al., 2017). The hedonic design of gamified systems offers the potential to generate a positive affective experience that enhances the users' perceived benefits and sustain continued usage of self-tracking technologies (Johnson et al., 2016). The use of gamification is known to evoke affective experiences (Hamari et al., 2018; Hassan et al., 2019) and satisfy intrinsic needs (Xi & Hamari, 2019a). The positive experience provided through the use of gamification could potentially have a direct contribution to well-being (Johnson et al., 2016).

Justifiably, the effectiveness of these motivational technologies needs to be corroborated with a body of empirical evidence supporting the promising beneficial effects (Hamari et al., 2014; Rapp et al., 2019).

2.4 Empirical evidence on the effect of gamification of physical activity

Existing literature primarily focused on whether gamified interventions of physical activity result in positive outcomes (Koivisto & Hamari, 2019a). While the success of gamification differs, the majority of empirical studies in this domain report positive results (Johnson et al., 2016; Koivisto & Hamari, 2019a; Mazéas et al., 2022). The effect of gamification on physical activity behaviour is described as ranging from a small to a medium positive effect in the short term (Mazéas et al., 2022). The long-term effect is even more volatile with very small to small effects being reported in literature (Mazéas et al., 2022). Some studies suggest that the positive

effect on physical activity declines over time during the intervention (Gremaud et al., 2018; Patel et al., 2019; Thorsteinsen et al., 2014) or is not maintained in the long-term when the gamification stimulus is removed (Maher et al., 2015). The positive effects reported for gamified interventions of physical activity are considerably higher when the gamified intervention is compared to inactive control groups (such as a group on a waiting list), rather than active control groups (such as a group using a non-gamified version of a mobile fitness application) (Mazéas et al., 2022).[1] Nonetheless, there is also evidence through randomised controlled studies reporting null effects for gamified interventions of physical activity (Direito et al., 2015; Edney et al., 2020; Kurtzman et al., 2018; Zuckerman & Gal-Oz, 2014).

The lack of randomised controlled studies isolating the effect of specific game elements or gamification designs limits our understanding on which gamification mechanisms are effective (Koivisto & Hamari, 2019a; Mazéas et al., 2022). The type of gamified interventions investigated in previous studies varies greatly and interventions are hardly comparable across the different studies (Koivisto & Hamari, 2019a; Mazéas et al., 2022). Nevertheless, literature provides some indications in this regard. Table 1 summarises existing empirical experimental studies investigating the effects of gamification of physical activity amongst adults.[2] The game design elements and mechanics utilised in previous studies were examined to identify the type of gamification design employed. Gamified interventions of physical activity implemented in previous studies are classified based on whether they were implemented in an individual setting or a group setting. Group-based interventions are in turn categorised as having either a competitive, cooperative or hybrid design. Table 1 also indicates whether study designs involved randomisation and control conditions, the type of measures used (objective or subjective measures) for physical activity outcomes, and the effects reported on physical activity behaviour and related outcomes.

[1] Effect size of 0.58 in the case of gamification versus inactive control group; and an effect size of 0.23 in the case of gamification versus active control group.

[2] Other studies involving interventions which are not classified as gamification are not included in Table 1. The distinction between gamification, serious games, pervasive games, and other related conceptual developments is clarified in Section 1.3.

Table 1: Summary table of existing empirical experimental studies investigating the effect of gamified interventions of physical activity (Source: Author)

Study	Gamified Design					Study Design			Outcome
Author/s, Year	**Individual setting**	**Group setting**	**Competitive**	**Cooperative**	**Hybrid**	**Randomisation**	**Control Group**	**Type of PA Measure**	**Effect**
Chen and Pu (2014)		Yes	Yes	Yes	Yes	Yes	No	Objective	**Positive effect:** Significant increase in physical activity in both the cooperation (by up to 21.1%) and the hybrid setting (by up to 18.2%). The effect in the competitive setting was also positive (increase by up to 8.8%) but not significant.
Corepal et al. (2019)		Yes	Yes		Yes	Yes	Yes	Objective	**Note**: This was a feasibility study, and no significance testing was conducted. From the data collected on PA outcomes, gamified interventions did not seem to increase PA.
Dadaczynski et al. (2017)	Yes	Yes	Yes, optional			Yes	Yes	Subjective	**Positive effect**: Increase in minutes walked, and positive effect on PA related knowledge, physical activity related self-efficacy and intentions.
Direito et al. (2015)	Yes					Yes	Yes	Objective	**Null effect**: No significant differences between interventions and control group in PA, perceived enjoyment, psychological need satisfaction, and self-efficacy.
Edney et al. (2020)		Yes	Yes			Yes	Yes	Both objective and subjective	**Null effect**: Although effect sizes moved in the expected direction, the increase in objective PA measures was not significant, even though there was an increase in the self-reported PA measures.
Gremaud et al. (2018)		Yes	Yes			Yes	Yes	Objective	**Positive effect**: Intervention group reported significantly more physical activity minutes than control group. Declining effects.

Study	Gamified Design					Study Design			Outcome
Author/s, Year	**Individual setting**	**Group setting**	**Competitive**	**Cooperative**	**Hybrid**	**Randomisation**	**Control Group**	**Type of PA Measure**	**Effect**
Harris (2018a, 2018b)	Yes	Yes	Yes			No	No	Subjective	**Positive effect**: Increase in self-reported physical activity and well-being when comparing pre- and post-intervention data.
Kurtzman et al. (2018)		Yes		Yes		Yes	Yes	Objective	**Null effect**: Gamified groups were not significantly more effective at promoting weight loss compared to control. In the gamified groups, teammates who lived together had greater weight loss than those living separately.
Lin et al. (2006)	Yes	Yes			Yes	Yes	No	Objective	**Positive effect** noted in both the individual and team conditions. No significant differences between the two experimental conditions.
Maher et al. (2015)		Yes				Yes	Yes	Subjective	**Positive effect:** Intervention group reported significantly more MVPA than control group. Declining effects. Participants were encouraged to achieve 10K steps/day and intervention focused on peer encouragement and support. **Null effect** on changes in quality of life (well-being) or vigorous PA at any timepoint.
Mo et al. (2019)		Yes			Yes	No	Yes	Subjective	**Positive effect:** Gamified group reported increased self-reported PA compared to control group. Results also showed increase in PA-related subjective norms, perceived behavioural control, and intention after the intervention compared to the control group.
Patel et al. (2017)		Yes		Yes		Yes	Yes	Objective	**Positive effect**: Gamified group reported significantly higher PA than control group. Declining effects.

Study	Gamified Design					Study Design			Outcome
Author/s, Year	**Individual setting**	**Group setting**	**Competitive**	**Cooperative**	**Hybrid**	**Randomisation**	**Control Group**	**Type of PA Measure**	**Effect**
Patel et al. (2019)		Yes	Yes	Yes		Yes	Yes	Objective	**Positive effect**: All gamified groups reported significantly higher PA than control group. Most effective design was competition, followed by the social support gamified design, and lastly the collaborative gamified group. Declining effects.
Paul et al. (2016)		Yes				No	Yes	Objective	**Positive effect**: Gamified group reported significantly higher PA than control group **Null effect** on well-being - no difference between groups on well-being measures.
Thorsteinsen et al. (2014)		Yes	Yes			Yes	Yes	Subjective	**Positive effect:** Intervention group reported significantly more physical activity minutes than control group (in week 5 and 9, but not week 12). Declining effects.
Tu et al. (2019)	Yes	Yes	Yes			Yes	No	Objective	**Positive effect:** Social / team based gamified app more effective than individualistic design.
Walsh & Golbeck (2014)		Yes				Yes	Yes	Objective	**Null effect**: No significant differences were found between the groups.
Zuckerman & Gal-Oz (2014)	Yes	Yes	Yes			Yes	Yes	Objective	**Null effect**: No significant differences were found between the gamified and non-gamified versions.

Note: PA = Physical activity

Gamified interventions incorporating competitive game design elements were reported to have a significant positive effect on physical activity behaviour in several studies (Gremaud et al., 2018; Harris, 2018a; Patel et al., 2019; Thorsteinsen et al., 2014; Tu et al., 2019). A competitive gamified intervention amongst overweight and obese adults facilitated the highest increase in physical activity, when compared to an individualistic gamified design that included social support, and a collaborative gamified design (Patel et al., 2019). Tu et al. (2019) reported that making the fitness application more social by incorporating a competitive design including a leaderboard ranking, adding friends amongst the team members, and providing opportunities for social support was more effective than an individualistic design that included badges, points, achievements, level of progression and virtual goods. Gremaud et al. (2018) reported that a gamified intervention incorporating competitive game elements significantly increased physical activity behaviour amongst sedentary office workers, compared to a non-gamified self-tracking experience. Self-reported measures of physical activity indicate that other gamified interventions involving competitive game elements also resulted in positive effects on physical activity (Harris, 2018a; Thorsteinsen et al., 2014).

While a competitive gamified design seems to be the most common gamification design investigated in gamification literature, empirical evidence also indicates that there is potential to increase physical activity through cooperative (Chen & Pu, 2014; Patel et al., 2017) and hybrid gamified designs (Chen & Pu, 2014; Lin et al., 2006; Mo et al., 2019). A cooperative gamified intervention led to a significant increase in physical activity among family members when compared to a control group (Patel et al., 2017). A gamified intervention involving teams and social support improved self-reported physical activity measures, as well as related cognitive constructs compared to the control group (Mo et al., 2019). Another study conducted by Lin et al. (2006) shows that both an inter-team competition (hybrid design) and an individualistic gamified design were effective at increasing physical activity. The study by Chen and Pu (2014) was the only study investigating three socially oriented gamification designs, namely competitive, cooperative, and hybrid. The authors developed *HealthyTogether*, a gamified mobile application encouraging dyads of friends to engage in physical activity together (Chen & Pu, 2014). In the absence of a control group, the authors compared physical activity during a one-week intervention period with a one-week baseline period. The cooperative gamified design facilitated the highest increase in physical activity,

followed by the hybrid gamified design. Albeit positive, the effect of the competitive gamified design was not significant (Chen & Pu, 2014).

Nonetheless, literature is inconsistent in suggesting one type of optimal gamification design that can facilitate an increase in physical activity behaviour. In addition to the need for further rigorous experimental studies that involve randomisation and controlled conditions (Koivisto & Hamari, 2019a) to isolate the effect of diverse gamification interventions (Mazéas et al., 2022), this field would greatly benefit from an in-depth understanding of how and why specific gamification elements or designs encourage or discourage user engagement and behaviour change (Hamari, 2013; Rapp, 2015).

So far, only few studies examine psychological outcomes and users' experiences resulting from gamified interventions of physical activity in conjunction to behavioural outcomes as the following observations suggest (Mazéas et al., 2022). Following a gamification intervention, positive psychological outcomes in terms of self-efficacy, physical activity intention, and knowledge were reported together with positive behavioural outcomes in terms of walking behaviour (Dadaczynski et al., 2017). Conversely, in response to a gamification intervention Direito et al. (2015) reported no net effects on perceived enjoyment, psychological need satisfaction and self-efficacy, as well as no effect on physical activity behavioural outcomes. Gamification literature posits that psychological outcomes resulting from gamification affordances mediates behavioural outcomes (Huotari & Hamari, 2017). The findings from Dadaczynski et al. (2017) and Direito et al. (2015) support this conceptualisation, however further research that empirically investigates the psychological and behavioural outcomes of gamification in the context of physical activity is necessary (Mazéas et al., 2022).

Examining users' experiences enhances our understanding on how specific gamification element/s or conditions contribute to or limit the effectiveness of such interventions (Rapp, 2015). Empirical evidence indicates that participants generally have positive experiences with gamified physical activity interventions or applications (Corepal et al., 2018; Kappen et al., 2018), but their engagement tends to decline over time (Rapp, 2015). Participants are gradually less interested due to the repetitive nature and lack of variety (Rapp, 2015). This is also reflected in the users' feedback gathered from other experimental studies investigating gamified interventions of physical activity (Corepal et al., 2018; Lin et al., 2006).

Equally, gamified applications incorporating a social setting enhance the users' motivation towards physical activity (Chen & Pu, 2014; Corepal et al., 2018). Social interaction and communication with other users were considered to be beneficial in facilitating social support (Chen & Pu, 2014; Consolvo et al., 2006; Corepal et al., 2018). Sharing and comparing physical activity data with others is generally regarded positively (Chen & Pu, 2014; Corepal et al., 2019; Edney et al., 2020; Peng et al., 2016). However, there are mixed reactions among users towards specific gamification designs and game elements. For instance, while competition could stimulate a sense of progression that is perceived as highly motivating (Thorsteinsen et al., 2014), it could also be discouraging when participants do not win (Corepal et al., 2019) or when others' performance is not within their range of ability (Chen & Pu, 2014). The competitive element is sometimes also considered unnecessary (Lin et al., 2006; Rapp, 2015). Therefore, introducing cooperative game elements along with competitive game elements could foster a more engaging experience (Rapp, 2015).

Integrating extrinsic reward elements in gamified applications do not necessarily improve the users' experience (Rapp, 2015). The users' qualitative feedback from previous studies indicated that sometimes extrinsic rewards were perceived as '*meaningless'* (Zuckerman & Gal-Oz, 2014, p. 7) and '*useless'* (Rapp, 2015, p. 74). Previous studies suggest integrating a combination of game elements that are linked to the users' efforts and are perceived useful or of value to the user (Kappen et al., 2020; Rapp, 2015). The game elements should support a sense of advancement towards specific goals (Rapp, 2015). Setting up goals and integrating game elements that provide a sense of progression (such as badges that reflect the users' effort) facilitate motivation for physical activity (Kappen et al., 2017).

Notwithstanding the popularity of fitness trackers and gamification in industry practice, empirical evidence supporting the claimed effects on well-being is scarce (Hermsen et al., 2016; Johnson et al., 2016; Rapp et al., 2019; Stiglbauer et al., 2019). Studies on the effectiveness of self-tracking of physical activity on well-being offer mixed evidence (Jin et al., 2022). The use of self-tracking technology was found to be an effective way to improve the quality of life and the individuals' well-being in corporate wellness programs (Giddens et al., 2017), among older adults (Suh & Li, 2022) and amongst breast cancer survivors (Vallance et al., 2007). Other literature (Stiglbauer et al., 2019) reports that self-tracking experiences of physical activity had a significant positive effect on the users' perceived physical health and

the sense of goal accomplishment. Albeit positive, the reported increase of overall psychological well-being was not significant (Stiglbauer et al., 2019). Likewise, Busch et al. (2020) reported that exercise-related self-tracking and step goals did not substantially influence psychological well-being. Conversely, there is also evidence which suggests that while self-tracking can increase the task performance, it may simultaneously have negative effects on subjective well-being including happiness and satisfaction by undermining the intrinsic motivation and enjoyment of performing such activities (Etkin, 2016). Thus, the effect of self-tracking of physical activity on the users' well-being calls for further study.

The majority of existing studies in the field of gamification of physical activity report positive effects on user experience, affect, cognition and behaviour that can have a positive impact on well-being (Johnson et al., 2016). However, studies investigating gamification of physical activity and its effect on quality of life and well-being remains scant (see Table 1 - Corepal et al., 2019; Harris, 2018b; Maher et al., 2015; Paul et al., 2016). A gamified community-wide physical activity intervention (Harris, 2018b) reported increases in both self-reported physical activity and mental well-being. Findings from other empirical studies (Maher et al., 2015; Paul et al., 2016) reveal that whilst gamification led to an increase in physical activity, there was no change on the quality of life or well-being measures reported.

2.5 Research gaps

There are mainly five research gaps in existing empirical evidence on the effect of gamification of physical activity (Johnson et al., 2016; Koivisto & Hamari, 2019a; Mazéas et al., 2022).

First, extant literature is unable to conclude that the reported positive effect on physical activity emerges from the implementation of gamification itself (Mazéas et al., 2022). Positive effects attributed to gamification in existing literature (Koivisto & Hamari, 2019a; Mazéas et al., 2022) involves location-based games (Broom & Flint, 2018; Kaczmarek et al., 2017), and exergames (Farrow et al., 2019; Garde et al., 2016; Geelan et al., 2016; Höchsmann et al., 2019) some of which also involve augmented and mixed realities. Although these interventions include game elements, these developments are conceptually different from gamification (Deterding et al., 2011; Fogg, 2002; Huotari & Hamari, 2012, 2017).

Second, literature indicates that empirical studies that did not include control groups report greater positive outcomes than studies that adopted a randomised controlled design (Koivisto & Hamari, 2019a). In the absence of a control group, studies rely on comparing levels of physical activity measured during the intervention period with baseline levels of physical activity taken prior to the intervention. Furthermore, even though some studies (Dadaczynski et al., 2017; Maher et al., 2015) included a control group, one cannot ascertain whether the gamified intervention or the physical activity tracker accounted for the behavioural change since the control group did not have access to a pedometer. Notwithstanding the operational issues, scholars recommend that future studies employ full randomisation and control conditions (Koivisto & Hamari, 2019a) with multiple groups to isolate the effect of different gamification elements or designs (Mazéas et al., 2022).

Third, several studies (Dadaczynski et al., 2017; Harris, 2018a, 2018b; Maher et al., 2015; Thorsteinsen et al., 2014) investigating the effect of gamification on physical activity behaviour rely on self-reported data using diaries or questionnaires, rather than objective data gathered through pedometers, accelerometers, or other sensor-based technologies. Subjective self-reported measures are based on the individuals' recollection of events which may not be as precise as those recorded through objective measures (Fiedler et al., 2021; Prince et al., 2008). For instance, Edney et al. (2020) report that while self-reported measures of physical activity indicated a significant positive effect, objective data gathered for the same study confirm that the intervention did not actually change the physical activity levels.

Fourth, apart from the fact that the number of rigorous empirical studies investigating gamification of physical activity are rather limited, existing studies vary greatly in terms of the motivational affordances included, the type of gamification design, as well as the outcome measures being investigated (Koivisto & Hamari, 2019a; Mazéas et al., 2022). The effect of gamification on physical activity tends to be difficult to compare as it is measured on diverse outcomes (Mazéas et al., 2022). Whilst the most common objective behavioural outcome measure is the daily step count, other measures used in literature include minutes of moderate-to-vigorous physical activity, active minutes, and walking time (Mazéas et al., 2022). Harmonising and standardising the gamified interventions, and the outcome measures on which the effect of gamification is investigated would be beneficial to compare like with like (Nacke & Deterding, 2017).

Fifth, there is scarce evidence on how gamified interventions of physical activity affect psychological outcomes together with behaviour change outcomes (Mazéas et al., 2022). Apart from the outcome measures investigating the behavioural change of physical activity, it would be beneficial to also look into the psychological outcomes to better understand the mechanisms related to behaviour change (Hamari, 2013; Mazéas et al., 2022) and other related outcomes (such as enhanced health or well-being) that gamification of physical activity may produce (Johnson et al., 2016). To achieve a comprehensive evaluation, it would be beneficial to employ mixed research methods to provide a rich insight into the process and the elements that invoked a motivating experience for users to increase their physical activity and explore other related outcomes (Aldenaini, Alqahtani, et al., 2020; Aldenaini, Oyebode, et al., 2020).

In summary, there is wide variation in study design and quality of existing empirical studies, lack of controlled designs, diversity in the study populations, varied targeted outcome measures, considerable statistical heterogeneity, and a high risk of bias in some of the reviewed studies which limits the conclusions that can be made (Johnson et al., 2016; Koivisto & Hamari, 2019a; Mazéas et al., 2022; Seaborn & Fels, 2015).

2.6 Research questions and hypotheses

To address the research gaps identified in existing literature, this thesis investigates three research questions:

Research Question 1: How does gamification of physical activity affect psychological and behavioural outcomes?

To answer the first research question relating to the psychological and behavioural outcomes resulting from gamification of physical activity, a four-arm randomised controlled field experiment is conducted. Consistent with established classification frameworks on gamification design (Liu et al., 2013; Morschheuser et al., 2017), this study examines three gamified designs commonly used in practice: 1) competitive; 2) cooperative; and 3) hybrid designs (reminiscent to the popularity of these social gamification designs used in mobile fitness applications). To my knowledge, the three socially oriented gamification designs have not yet been investigated in a randomised controlled setting in the physical activity domain.

The data gathered includes a panel dataset of step counts (objective data) to investigate the causal effect of gamification on step counts (behavioural change), as well as self-reported data to examine the effect of gamification on the users' intrinsic motivation and perceived usefulness of the experience. Perceived enjoyment and interest reflect the individual's emotional psychological response to the intervention and are considered to be self-report measures of the individuals' intrinsic motivation (Ryan, 1982). By contrast, perceived usefulness is a widely used measure in studies examining internalisation of extrinsically motivated behaviours (Wu & Lu, 2013).

Based on the theoretical foundations and literature discussed in this chapter, the data gathered through the field experiment shall be analysed to test the following hypotheses:

Hypothesis 1: Gamification improves physical activity - Gamified groups will report higher step counts than the control group during the intervention period.

Hypothesis 2: Hybrid (competitive-cooperative) design will facilitate the strongest effect on physical activity.

Hypothesis 3a: Gamified groups will report higher intrinsic motivation than the control group.

Hypothesis 3b: Gamified groups will report higher perceived usefulness than the control group.

Research Question 2: Do experiences of gamification and self-tracking of physical activity create positive emotional, cognitive, and behavioural responses that yield enhanced well-being?

While literature suggests that wearable physical activity trackers and gamification can have beneficial effects on users' well-being (Johnson et al., 2016), the effectiveness of these behavioural interventions has not been sufficiently examined (Hermsen et al., 2016; Johnson et al., 2016; Rapp et al., 2019; Stiglbauer et al., 2019). In view of this shortcoming identified in existing literature, this thesis questions whether experiences of self-tracking and gamification create positive emotional, cognitive, and behavioural responses that yield enhanced well-being.

To answer this question, this study utilises data from a longitudinal survey study measuring well-being (*life satisfaction* and *happiness*) before and after an experience of self-tracking

alone and in conjunction with gamification. The individuals' emotional and cognitive psychological responses, as well as the individuals' behavioural change in physical activity are measured to examine the resultant effect on well-being. Based on the theoretical underpinnings and literature presented in this chapter, this study postulates that the use of self-tracking technologies and gamification can enhance well-being by eliciting positive emotional, cognitive, and behavioural responses based on hedonic and utilitarian benefits respectively. Furthermore, the study posits that the use of gamified (relative to non-gamified) self-tracking experiences results in stronger emotional, cognitive, and behavioural responses, and as a result enhanced well-being.[3]

Specifically, the data gathered through this longitudinal study on well-being outcomes tests the following hypotheses:

Hypothesis 4: The use of gamification enhances the effect on well-being (relative to a non-gamified self-tracking experience).

Hypothesis 5: Enjoyment and interest enhance well-being gain (*Enjoyment and Interest* reflect the users' emotional response to the intervention based on the hedonic benefit of the experience)

Hypothesis 6: Perceived usefulness of the experience enhances well-being gain (*Perceived usefulness* reflects the users' cognitive response to the intervention based on the utilitarian benefit of the experience)

Hypothesis 7: A positive change in physical activity behaviour enhances well-being gain (*Physical activity* is a behavioural outcome measure that is expected to enhance well-being).

[3] Literature presented in Section 2.2.3 suggests that both competitive and cooperative designs could stimulate motivation and enhance well-being. Thus, H4 examines the data from all the gamified groups (relative to the non-gamified group). Nonetheless, statistical tests shall be carried out to check for any significant differences in the well-being gains reported between the different gamified intervention groups.

Research Question 3: How do gamified self-tracking experiences foster motivation towards physical activity?

A qualitative study shall explore the users' subjective experiences of using wearable physical activity trackers for self-tracking in conjunction with gamification. This study determines the perceived impact of the employed elements, including any potential negative implications. The findings seek to elucidate several practical implications that could allow industry practitioners and researchers to design more engaging gamified systems. Specifically, this study is expected to contribute to gamification literature by:

- Gathering insights into the users' experiences of self-tracking of physical activity and the use of gamification.
- Identifying the motivational affordances that encouraged users to engage in physical activity and the perceived impact of the employed elements, including any potential negative implications.
- Explore the underlying psychological processes through which gamified self-tracking experiences motivated users towards the desired behavioural change.

Outlining practical implications which could allow industry practitioners and researchers to design more engaging gamified systems.

2.7 Conclusion

This chapter presented the theoretical frameworks and conceptual underpinnings related to motivation, behaviour change and gamification design. The literature related to the field of application chosen for this thesis (physical activity) and the theoretical underpinnings of how gamification and self-tracking of physical activity can enhance well-being were also discussed. Subsequently, this chapter presented a review of existing empirical evidence on the use and effect of gamification in the context of physical activity. The research gaps were explained, followed by the research questions and the hypotheses set out for this thesis.

A summary of the hypotheses specified in this section and the key literature pertaining to each hypothesis is presented in Table 2.

Table 2: Summary table outlining the hypotheses and key literature related to each hypothesis.

Hypotheses	**Key literature relating each hypothesis**
H1: Gamified groups will report higher step counts than the control group during the intervention period	Johnson et al., 2016; Koivisto & Hamari, 2019; Mazéas et al., 2022
H2: Hybrid design will facilitate the strongest effect on step counts	Tauer & Harackiewicz, 2004; Morschheuser et al., 2019
H3: Gamified group will report higher intrinsic motivation and perceived usefulness than the control group	Johnson et al., 2016; Cheng et al., 2019
H4: The use of gamification enhances the effect on well-being relative to a non-gamified self-tracking experience	Johnson et al., 2016; Cheng et al., 2019
H5: Enjoyment and interest enhance well-being gain	Ryan & Deci, 2000b
H6: Perceived usefulness of the experience enhances well-being gain	Ryan & Deci, 2000b
H7: A positive change in physical activity behaviour enhances well-being gain	Abdin et al., 2018; Penedo & Dahn, 2005; Wiese et al., 2018

The review of empirical evidence highlights the need for rigorous studies to investigate the effect of different gamification designs in a comprehensive manner. Through a combination of research methods (explained in Chapter 3), this thesis aims to develop a better understanding on the effect of different gamified designs, exploring both the psychological and behavioural outcomes, as well as the underlying processes which led to these effects.

3 Methodology

3.1 Introduction

The research questions (specified in Section 2.6) establish what knowledge development this thesis aims to achieve. The methodology chapter provides an explanation and justification for the philosophical approach and methodological choices adopted in this thesis to answer these research questions. The critical realism philosophical stance adopted for this thesis is discussed in Section 3.2, followed by an explanation of the mixed methods research methodological choice in Section 3.3. The details pertaining to the three different research strategies including the study design, time horizon, participants and setting, data collection procedure and data analysis techniques are presented from Section 3.4 to Section 3.6. Finally, this chapter concludes with a discussion about the ethical issues in Section 3.7, followed by validity and reliability issues in Section 3.8.

3.2 The research philosophical stance

The philosophical point of view adopted by a researcher reflects the *'beliefs and assumptions about the development of knowledge'* (Saunders et al., 2009, p. 130). These beliefs and assumptions ultimately shape how the research is undertaken in terms of the choice of the research method, the research strategy, as well as the data collection and analysis techniques (Saunders et al., 2009).

The spectrum of research philosophies varies in terms of the ontological, epistemological and methodological assumptions (Easterby-Smith et al., 2012; Saunders et al., 2009). The two major contrasting research philosophical stances in social science are *positivism* and *social constructionism* (Easterby-Smith et al., 2012). The *positivist* paradigm assumes that reality is objective, external and can be studied through empirical objective methods that yield pure data uninfluenced by human interpretations (Easterby-Smith et al., 2012). On the other hand, the *social constructionist* (also referred to as the *interpretivist*) paradigm assumes that reality is socially constructed and there could be multiple realities and interpretations, which are best understood through qualitative methods of analysis (Easterby-Smith et al., 2012). These two opposing research paradigms were deemed to be unsuitable for this thesis, because while an objectivist view is considered to be suitable to establish the causes and effects of the

phenomena being studied, it does not adequately take into account the complexities of social structures that impact individuals' behaviours.

This thesis is approached from a *critical realist* perspective, which lies between positivist and interpretivist extremes. Critical realism shares the interest of positivism in terms of finding causalities and patterns in the objective world, while also seeking to identify the deeper underlying mechanisms which generate the empirical phenomena (Alvesson & Sköldber, 2009). The notion of reality (ontology) from a critical realist perspective is stratified into three domains – the empirical, the actual and the real (Bhaskar, 2008). The *empirical* domain refers to what can be observed and experienced, which is a subset of the *actual* domain, that includes events generated from mechanisms which lie at a broader level, as part of the *real* domain (Bhaskar, 2008). Reality is external and independent from the researcher, yet it may not be directly accessible to observe (Bhaskar, 2008). The quest for a critical realist is to explore the deeper reality and how this relates to the other two ontological domains (Alvesson & Sköldber, 2009; Danermark et al., 2019).

Critical realism suggests that the context of social sciences is an open system, where events and phenomena happen in a complex environment through the underlying mechanisms, structures and conditions that are ever-changing and context-dependent (Bhaskar, 2008). These ontological assumptions lead to the epistemological assumption that our knowledge is relative to who we are, what we see and what we experience, thus implying epistemological relativism (Archer et al., 2013). Knowledge is historically and socially situated, and our interpretations of knowledge are thus fallible (Archer et al., 2013). Acknowledging that our knowledge of reality is a result of social conditioning, critical realists' inquiry is value laden. Thus, critical realist researchers strive to minimise bias and errors, and aim to be as objective as possible (Saunders et al., 2009).

The notion of causality for a critical realist cannot be reduced to simply observing facts through statistical models. Instead, adopting a range of mixed methods enables researchers to capture the deeper underlying causal mechanisms that create the conditions for different effects and events to materialise (Alvesson & Sköldber, 2009). These assumptions helped to guide the empirical investigations and shape the methodological choices and research strategies adopted for this thesis. The next section explains the range of mixed methods adopted to investigate the

research problem in an objective and rigorous manner, while exploring related underlying connections and mechanisms associated with the phenomena being investigated.

3.3 Research design

Consistent with the critical realist philosophical position adopted for this thesis, a mixed methods research design was considered to be the most appropriate methodological choice to answer the research questions specified for this thesis. A mixed methods research design supports a comprehensive approach in investigating the effect of gamification on diverse outcomes, and also reveal insights into the process, mechanisms and conditions that manifest the observed behavioural change (Aldenaini, Alqahtani, et al., 2020; Aldenaini, Oyebode, et al., 2020). Combining quantitative and qualitative techniques allows researchers to address broader questions that capture multiple facets of the phenomenon being investigated (Creswell & Plano Clark, 2011; Easterby-Smith et al., 2012). This thesis adopted a systematic and planned research approach that involved three different research strategies to answer the research questions set out for this thesis (see Table 3) following three key considerations.

First, in view of the limited empirical evidence on the effect of gamification on physical activity, **a randomised controlled field experiment** was designed and conducted to provide evidence on the effect of different gamification design interventions. A randomised controlled trial is considered to be the most rigorous form of research method in order to isolate and estimate the effect of a treatment (Twisk et al., 2018). Consistent with established classification frameworks on gamification design identified in literature (Liu et al., 2013; Morschheuser et al., 2017), this thesis examined three gamification designs (competitive, cooperative, and hybrid) commonly used in practice. For this study, a longitudinal panel dataset of daily step counts was gathered and analysed to examine the effect of gamification on physical activity, and how the design choice of gamification affected physical activity outcomes. Data on the users' motivation and perceived usefulness was also gathered through **a survey** conducted at the end of the experiment to examine the effect of gamification on psychological experiential outcomes. The experiment protocol is set out in Section 3.4.

Second, this thesis investigated whether behavioural change interventions, namely self-tracking, with and without gamification influenced the individuals' well-being. **A longitudinal two-wave survey study** was conducted to gather self-reported data on well-being measures

before and after the experimental study utilised to answer research question one. The data gathered (for RQ1) on the individuals' emotional and cognitive psychological responses, as well as the individuals' behavioural change in physical activity (based on the step counts) were utilised to parse out the resultant effect of these outcomes on the users' well-being. Furthermore, data on potential predictors of physical activity and well-being, including demographic, lifestyle, and psychological factors was also collected. Through this data, it was possible to examine the individual traits associated with well-being.[4] Details about this research strategy are explained in Section 3.5.

Third, a **qualitative study** involving focus groups and one-to-one interviews was conducted to gain deeper insights on how gamification and self-tracking could be utilised to foster motivation towards physical activity (RQ3). This qualitative study identified the motivational affordances that encouraged users to engage in physical activity and explored the underlying psychological processes that facilitated the users' motivation towards physical activity. Both positive and any potential negative reactions related to the gamification mechanisms and self-tracking were explored. Findings from a sequential explanatory qualitative study can enrich the findings from a quantitative study conducted earlier by reflecting upon the experience (Ivankova et al., 2006; Tashakkori & Teddlie, 2010). Moreover, the findings from this qualitative study could allow industry practitioners and researchers to design more engaging gamified systems. Details about this research strategy are explained in Section 3.6.

[4] As additional analysis, the individual traits associated with physical activity were examined. The analysis and results related to the individual traits of physical activity are presented in Appendix F.

Table 3: Outline of each research study, data collected and data analysis techniques to answer each specific research question

	Answering research question	Research strategy	Research design	Data collected	Analysis of data
1	RQ1: How does gamification of physical activity affect psychological and behavioural outcomes?	Four-arm randomised controlled field experiment (Section 3.4)	Quantitative causal research	Objective data: a longitudinal panel dataset of step counts gathered through wearable devices to examine the behavioural outcome. Subjective data: self-reported data on the users' interest and enjoyment (intrinsic motivation) and the users' perceived usefulness of the experience.	Generalised linear mixed models using the longitudinal data analysis of covariance method. Inferential statistics using Mann-Whitney and Kruskal-Wallis tests for the comparison of mean scores.
2	RQ2: Do experiences of gamification and self-tracking of physical activity create positive emotional, cognitive, and behavioural responses that yield enhanced well-being?	Longitudinal survey study (Section 3.5)	Quantitative explanatory study	Subjective data on well-being outcomes and self-reported control measures related to well-being.	Inferential statistics including Wilcoxon Signed Ranks, Mann-Whitney tests, ANCOVA, and a gain score regression analysis for each well-being outcome. Multivariate linear regression analysis for each well-being outcome to estimate the models for baseline life satisfaction and happiness, and the gains reported in these well-being outcome measures.
3	RQ3: How do gamified self-tracking experiences foster motivation towards physical activity?	Focus groups and interviews (Section 3.6)	Qualitative corroborative study	Subjective data on the users' experiences.	Reflexive thematic analysis

3.4 Research strategy 1: Randomised controlled field experiment

A randomised controlled field experiment was designed and conducted to gather data to answer the following research questions:

> *RQ1: How does gamification of physical activity affect psychological and behavioural outcomes?*

3.4.1 Study design and timeline

This study involved a four-arm randomised controlled field experiment, examining the effect of three gamified interventions versus a control group. The treatment groups involved three different gamification designs (1 - competition; 2 - cooperation; 3 - hybrid design involving an-inter team competition). This study involved a parallel group design, where each participant was allocated to one group throughout the experimental period. The four-week experimental period consisted of a one-week baseline period, followed by a three-week intervention period. The randomised controlled experiment was conducted between January and March 2020 following the timeline[5] set out in Figure 2.

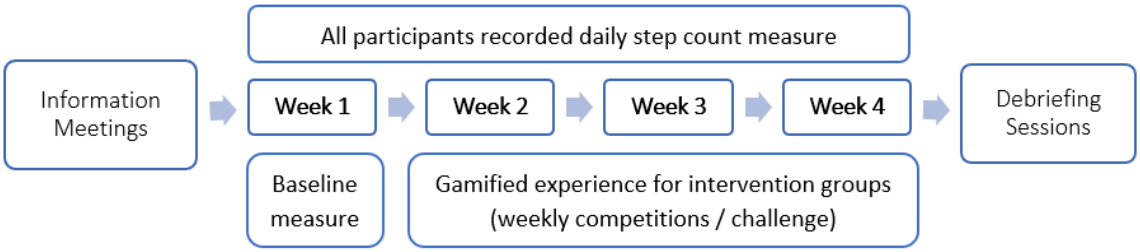

Figure 2: Study timeline

3.4.2 Participants and setting

The study population included academic researchers and post-graduate research students. Previous research suggests that people involved in academia typically lead a sedentary lifestyle that does not meet the recommended levels of physical activity, leading to higher risks of non-communicable diseases related to lack of physical activity (Cooper & Barton, 2016). The study was conducted in Malta, a country with a high prevalence rate of insufficient physical activity and high rates of overweight and obese people (WHO, 2018b, 2022).

[5] The experiment was completed prior to COVID-19 outbreak in Malta.

Participants were recruited over a two-month period starting in December 2019 using a non-probabilistic convenience sampling method. Following an email invitation[6] sent through an academic institution and a post on social media, interested participants were invited to review the information about the study (including its objectives, duration, and requirements) and provide informed consent through the link provided. Participants were eligible for this study if they were:

- over 18 years of age,
- did not use a smartwatch or a wearable to monitor their physical activity during the previous 12-month period[7], and
- had no health issues (such as heart condition, chest pain, bone or joint pain, or dizziness) that they are aware of, which could prevent them from engaging in physical activity.

Participants were ineligible if they were currently pregnant or have been told by their doctor not to engage in physical exercise.

3.4.3 Sample size

Calculation of the sample size was based on the recommended guidelines on sample size estimation for randomised controlled trials suggested by Chow et al. (2017). On the basis of previous literature (Gremaud et al., 2018), the expected difference in daily steps between the gamified intervention groups and those in an active control group using a wearable device was around 2000 steps per day. The standard deviation was assumed to be about 2500 steps per day. The sample size required to establish superiority of the gamified interventions compared to the control group was based on a targeted power of 80% ($1 - \beta = 0.8$) at 5% significance level ($\alpha = 0.05$) with equal allocation between the groups ($k = 1$). The sample size calculation indicated that 20 participants were required for each treatment group and control group respectively. Thus, for a four-arm randomised controlled experiment a total sample size of 80 participants is required to detect between-group differences on the daily step count.

[6] The recruitment email and the information and consent form are included in Appendix B.
[7] Even though eligibility criteria excluded participants who used a smartwatch during the previous 12-month period, 22.5% of participants claimed that they had prior usage of wearables at some point before the study.

3.4.4 Randomisation

Following the eligibility screening criteria, a Unique Reference Number (URN) was assigned to all participants to ensure anonymity all throughout the study. Using an online random sequence generator (random.org), eligible participants (n = 80) who provided informed consent were randomly allocated to the control or one of the treatment groups using a 1:1:1:1 ratio. Participants were blinded to group allocation and groups were colour-coded to hide the identity of each group from participants.

3.4.5 Procedure and interventions

All participants attended a group information meeting (see Figure 2). Separate information meetings were held for each group of participants to avoid cross-contamination between groups. During the information meeting, all participants were given a smartwatch (Xiaomi Mi Band) to monitor their physical activity. Earlier studies (Tam & Cheung, 2019; Xie et al., 2018) show that these wearable devices are adequately reliable in measuring step counts, and hence these were preferred against other brands of pedometers due to their cost and battery lifespan. The use of wearable devices permits the collection of objective data. Literature indicates that objective data is a more reliable measure of physical activity than self-reported data based on recall (Fiedler et al., 2021; Prince et al., 2008).

All participants were instructed on how to pair and sync the smartwatch with the corresponding mobile application, and to wear the device at all times.[8] During the set-up of the wearables and the corresponding application installed on their smartphones, all participants were allowed to choose a personalised daily step target. Goal setting is a commonly used feature in self-tracking technologies (Aldenaini, Oyebode, et al., 2020) that supports users' intrinsic motivation and self-regulation (Latham & Locke, 1991).

Control group

Participants in the control group were equipped with a smartwatch that enabled them to monitor their physical activity but were not exposed to gamification elements. The control group could

[8] The battery lasts approximately two weeks. Participants had to charge their wearable device only once during the experiment and were advised to do so during the night.

only monitor whether they achieved their personal daily step goal target set on their smartwatch. This study adopted an active control group to ensure that the observed effect on physical activity is not the result of having a wearable device to monitor physical activity. Empirical evidence (Mazéas et al., 2022) concluded that the positive effects reported for gamified interventions are considerably higher when gamification was compared to inactive control groups such as individuals on waiting lists, rather than active control groups where participants utilised a wearable device to track their physical activity.[9]

Interventions

A gamified platform (pointagram.com) was used to design a separate gamified experience for each treatment group.[10] All participants could access the gamified platform through an application that was installed on their smartphone or through a web browser.

The design of the gamified interventions was guided by the taxonomy of gamification concepts utilised in health applications (Schmidt-Kraepelin et al., 2018) and gamification design frameworks (Buckley et al., 2018; Liu et al., 2017; Morschheuser et al., 2017) identified in literature. The game elements and principles implemented in the interventions, and the desirable outcomes are detailed in Table 4.

Following consideration of the psychological model of the self-determination theory (Ryan & Deci, 2000b), all the gamified interventions incorporated a common set of game elements related to the motivational constructs of the self-determination theory to afford an appealing and motivating experience that supports the users' intrinsic motivation (Buckley et al., 2018). These included points, badges, progress feedback and opportunities for social support, comparison and interaction on the newsfeed section of the gamified application. Participants were asked to enter their daily step count to achieve points (one point for each step count recorded). Based on their daily step count, individual badges were awarded at increments of 2K step counts, starting from a 2K badge going up to a 20K badge. Participants could see others' performance (social comparison) and interact with other participants in their respective

[9] Effect size of 0.58 in the case of gamification versus an inactive control group; and an effect size of 0.23 in the case of gamification versus an active control group.
[10] Each treatment group had a separate gamified interface on the platform, so the participants in the gamified groups would not become aware of the other groups.

group through posts, comments, and likes (social interaction and support). Screenshots from the gamified application are set out in Figure 3 to Figure 5. Further visual images on the experimental procedure are included in Appendix A.

Furthermore, based on the classification of gamification features proposed by Morschheuser et al. (2017) that is grounded on the social interdependence theory (Johnson, 2003) each gamified intervention incorporated specific game elements to create 1) a competitive gamified design; 2) a cooperative gamified design; and 3) a hybrid (competitive-cooperative) gamified design. Participants in the **competitive treatment group** had a weekly individual competition, where the accumulated points were visible on a leaderboard (Figure 4) and the top three players were awarded a virtual trophy. By contrast, participants in the **hybrid (competitive-cooperative) treatment group** had a weekly inter-team competition (participants were randomly assigned in teams of four participants each) where the accumulated points of each team were visible on a leaderboard (Figure 4) and the top three teams were also awarded virtual trophies.

Finally, the **cooperation treatment group** had a weekly group challenge (quest) to reach a target step count (shared goal) by the end of the week. Their steps were accumulated and depicted on a visualisation of a pirate making his way to reach the treasure chest on an island, with a countdown timer indicating the time left for the participants to complete the challenge (Figure 5). The group target step count was 700K steps for the first week (based on approximately 5K daily step count per participant) and then increased every week based on the equivalent of 7.5K and 10K daily step counts per participant as a group target. All the challenges and competitions were scheduled to run on a weekly basis from Monday to Sunday.

Table 4: Gamification design of the interventions

Gamification Design	
Gamification design principles, elements and mechanics	*Applicable to ALL gamified interventions:* ▪ *Points:* users earn individual points for step count recorded (one step = one point). ▪ *Badges:* users earn individual badges for achieving higher daily step counts. ▪ *Progression status*: progression bar indicating the progress and remaining effort required to achieve the next badge. ▪ *Opportunities for social interaction and support:* users can post comments, send likes to each other comments and notifications on the newsfeed section of the gamified application. ▪ *Opportunities for social comparison:* users can see others' performance, progress and achievements. ▪ *User identity*: users are anonymised and represented by a URN code. ▪ *Feedback:* users are notified when they earn points and badges through a notification on the gamified application. ▪ *Episodical:* competitions and challenges/quests run from Monday to Sunday, users' progress in the competition / challenge resets every week. *Applicable to the Competitive Gamified Design (Player vs. Player competition):* ▪ *Leaderboard:* showing the ranking of all the players ▪ *Virtual trophies:* awarded to the top three players with the highest step counts *Applicable to the Hybrid Gamified Design (Team vs. Team competition):* ▪ *Teams:* players were randomised to teams of 4 players each ▪ *Leaderboard:* showing the ranking of all the players ▪ *Virtual trophies:* awarded to the top three teams with the highest step counts *Applicable to the Cooperative Gamified Design (Shared group challenge/quest):* ▪ *Visualisation /Plot:* a map showing a pirate making his way to reach the treasure chest with a countdown timer indicating the time left for the participants to complete the challenge. Users' step counts are reflected in the progress that the pirate towards the treasure chest. ▪ *Challenge:* Quest to reach a target step count (shared goal) which automatically opens the pirate treasure chest by the end of the week.
Desirable outcomes	Behaviour change - Increase in physical activity (step counts).
	Positive psychological responses in terms of perceived enjoyment and interest (intrinsic motivation) and perceived usefulness of the experience. Positive impact on the users' well-being.

Points and badges visible on News Feed **Social Interaction**

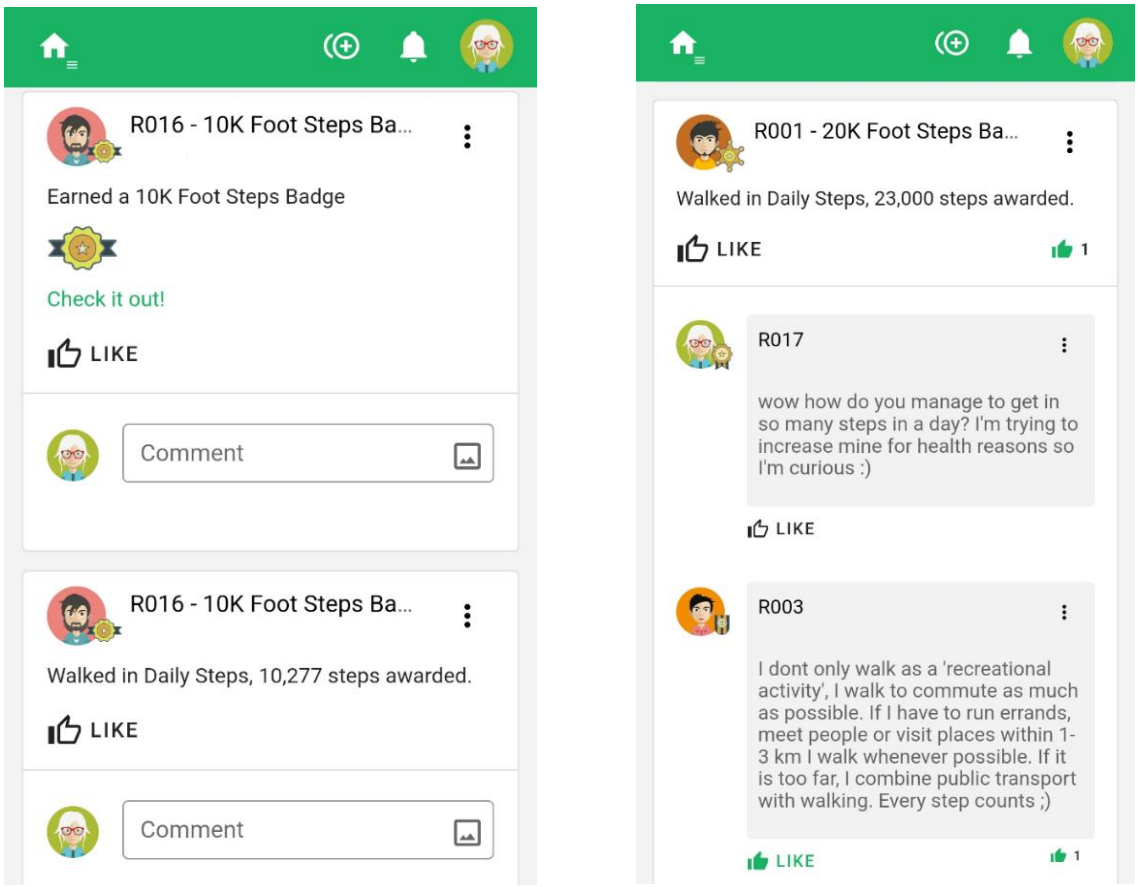

Figure 3: Screenshots from the gamified application

The game elements and design principles implemented for this study are amongst the most commonly adopted gamification design strategies in industry practice. This is also verified with the taxonomy of game elements utilised in gamified fitness applications published by Neupane et al. (2020).

At the end of the study, all the participants were asked to return their wearable devices. At this stage the step count data which was being recorded through the participants' smartwatches and the corresponding application that was installed on the participants' smartphones was collected. During this meeting, all participants were also asked to complete a pen-and-paper questionnaire to measure the participants' interest and enjoyment during this experience, their perceived value and usefulness of the experience, as well as demographic information and lifestyle characteristics.

Competition Leaderboard: Player vs. Player **Teams Leaderboard: Team vs. Team**

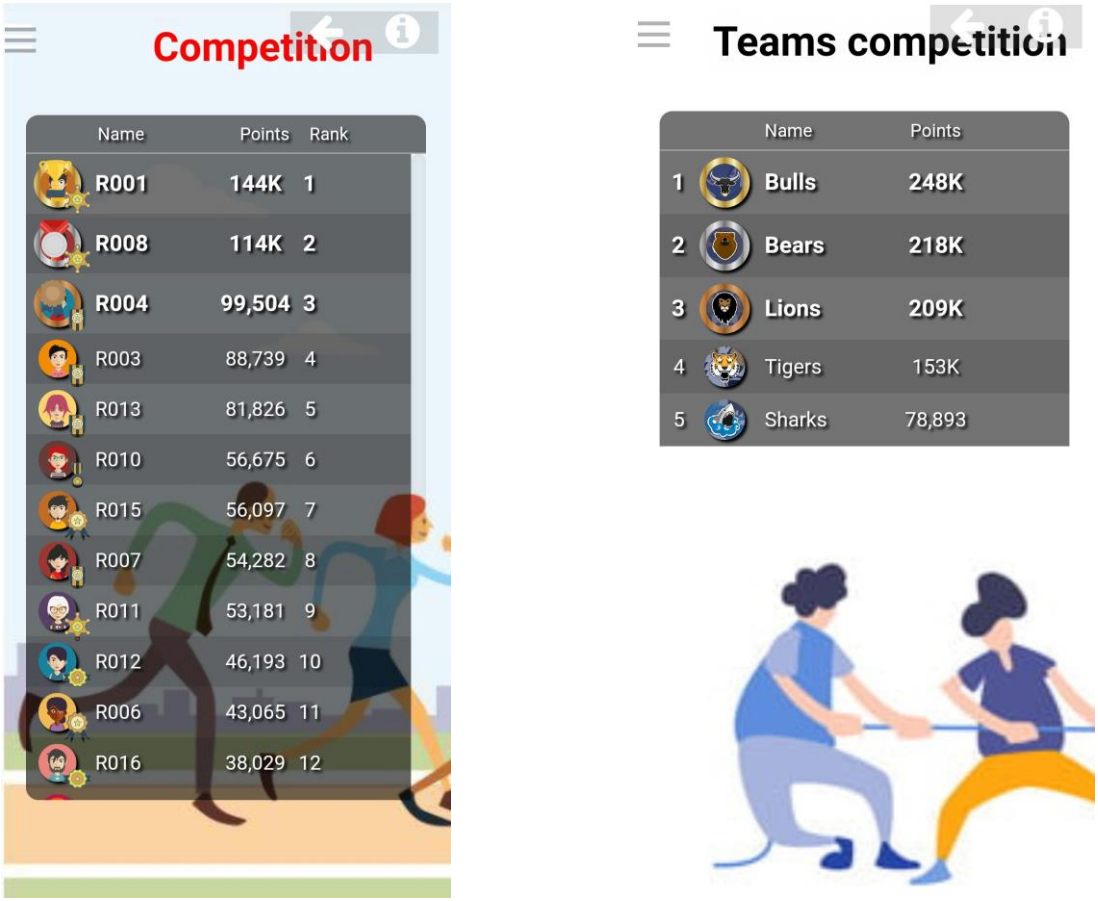

Figure 4: Screenshots showing the leaderboards used in the competition and hybrid gamified groups

Cooperative Group Challenge

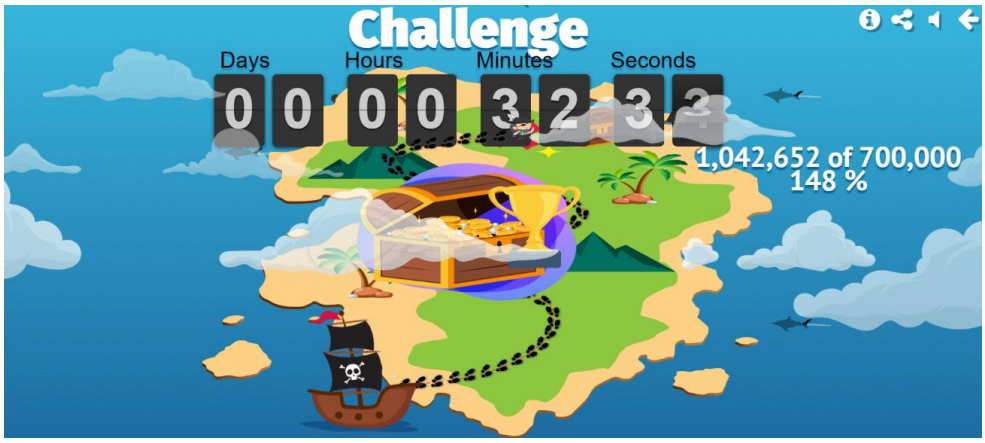

Figure 5: Screenshot showing the cooperative group challenge

3.4.6 Outcome measures

The behaviour change in physical activity was measured in terms of the change in step counts. Step counts were recorded daily as a continuous variable. The panel dataset considered for this study included four weeks of step count data, each week starting on Monday. Earlier studies suggested that the most reliable measures are achieved when monitoring of step count data starts on Monday (Sigmundová et al., 2013). The first week of step count data was considered as the baseline measure, during which no treatment was administered, whilst the following three weeks of step count data were during the intervention period.

The psychological outcomes were measured in terms of the participants' intrinsic motivation (based on the users' interest and enjoyment) and the users' perceived value of the experience. Self-reported data on these experiential outcomes was gathered using adaptations of the Intrinsic Motivation Inventory (IMI), which is a validated instrument based on the self-determination theory (McAuley et al., 1989; Ryan, 1982). The Interest/Enjoyment subscale of the IMI is considered as a validated self-reported measure of intrinsic motivation (McAuley et al., 1989; Ryan, 1982). The Perceived Usefulness subscale of the IMI refers to the perceived value of an activity which facilitates internalisation and self-regulation of activities that are found to be useful (Deci et al., 1994). Table 5 presents the details on the scale items for each construct.

Table 5: Measure, items and scales

Measure	Source	Item wording	Notes
Intrinsic Motivation *(Emotional response)*	Adapted from the Interest / Enjoyment sub-scale of the IMI	I enjoyed doing this experience very much	7-point Likert scale anchored 'Not at all true' to Very true'
		This experience was fun to do	
		I thought this was a boring experience (R)	
Perceived Usefulness *(Cognitive response)*	Adapted from the Value / Usefulness sub-scale of the IMI	I believe this experience was of some value to me	7-point Likert scale anchored 'Not at all true' to Very true'
		I think that doing this experience was useful to increase my physical activity	
		I think doing this experience helped me to increase my physical activity	

3.4.7 Statistical data analysis

Data cleaning and handling of missing data

All randomly assigned participants were included with the intention-to-treat principle, and thus all participants were included in the analysis. Step count data on the days when smartwatches were given to participants during the initial information meetings was discarded since this did not capture full-day data of the physical activity of participants. The following two days of initial wearable use which were on weekend days were not included in the baseline estimate due to potential higher activity during initial wearable use. This approach is similar to that adopted in previous studies (Patel et al., 2017, 2019).

Days with unrecorded steps could result if a participant did not wear the wearable device, or the device did not synchronise with the smartphone application. Research on pedometer monitoring indicates that three days of step count data within a week can provide a sufficiently reliable estimate of physical activity (Tudor-Locke et al., 2005). Missing step count data throughout the experiment period accounted for only 1.6% of the total observations (35 out of 2,240 participant-days). This amount of missing step count data is much lower than other previous studies where missing data ranged from 19% to 29% in previous physical activity interventions with longer timeframes (Chokshi et al., 2018; Patel et al., 2017, 2019). Missing step counts were imputed with the weekly mean step count. The mean daily step count for each week was derived by summing up the daily step count for each respondent and dividing it by the number of days on which step counts were recorded.

Previous literature suggests that daily step count values that are less than 1000 steps do not reflect full day data activity and should thus be excluded and imputed (Kurtzman et al., 2018; Patel et al., 2017). In this study, step counts values less than 1000 accounted for only 1% of the total observations, and these were imputed at the weekly mean step count.[11]

Data analysis of behavioural outcome

Data was restructured into the long data format and analysed using Generalized Linear Mixed-Effect Models (GLMM) in STATA™ (version 16.1, StataCorp). GLMMs were used for the

[11] Details about the missing step data for each group and the number of participant-days with step count data less than 1K step count per day are presented in Appendix D: Supplementary material for quantitative results.

analysis of this dataset because these statistical models handle multi-level or repeated data, where the dependent variable is not necessarily normally distributed and are able to handle missing observations in the dataset. GLMM combines the concept of generalised linear models with linear mixed models. Specifically, GLMM is an extension of the generalised linear model, where the linear predictor contains random effects in addition to fixed effects. Also, the GLMM extends the linear mixed models to response variables that have a non-normal distribution (Stroup, 2012).

In view of the repeated observations for each subject and the multi-level structure of the dataset where each subject is nested within a group, mixed model analysis was deemed to be the most appropriate method of analysis for this dataset (Snijders & Bosker, 2011; Stroup, 2012; Twisk et al., 2018). In this case, the correlations between the repeated measures of step count scores were all positive and high (ranging from 0.791 to 0.847).[12] Therefore, statistical methods of analysis which assume independence of observations and ignore such correlations were not appropriate.

The effect of gamification (*Treatment*) was estimated using the longitudinal analysis of covariance adjusting for the baseline values of the outcome variable, even though the differences at baseline are attributed to chance and random fluctuations (Twisk et al., 2018).[13] The generalized mixed-effects model analysis also included a random intercept to adjust for the repeated observations over time at individual level and was estimated using a robust estimator of variance. Statistical models computed using robust standard errors cater for heteroskedasticity and serial correlation within panels (White, 1980).

For the first hypothesis *(H1: Gamification improves physical activity)*, gamified groups were expected to report higher step counts than the control group during the intervention period. The overall effect of gamification *(Treatment)* on the mean daily step count was estimated by analysing the change in the mean daily step count for the gamified group in comparison to the

[12] Correlation matrix included in Appendix D: Supplementary material for quantitative results.
[13] When the data is analysed using longitudinal data analysis techniques, an adjustment for the baseline differences of the outcome variable is recommended (even though the differences at baseline are not significant), to provide a precise estimate of the treatment effect. If no adjustment is made for the baseline differences in the outcome variable, an artificial intervention effect may be estimated due to the regression to the mean. By including the baseline daily step count as a covariate in the analysis and taking repeated measures of the outcome measure, this study aims to reduce error variability, thus leading to a possible increase in the attained power.

control group from the baseline period to the intervention period. The mean daily step count before the intervention started was taken as the baseline measure (*Baseline Steps*). The dependent variable (*Intervention Steps*) was the mean daily step count during the intervention period. The effect of gamification was estimated using the longitudinal analysis of covariance model as recommended by Twisk et al. (2018) (see Equation 1):

Y_t ➔ *Intervention Steps: the mean daily step count during the intervention*

X ➔ *Treatment (0 for control and 1 for gamified treatment)*

Yt_0 ➔ *Baseline Steps: the mean daily step count at baseline*

Equation 1*:* $Y_t = \beta_0 + \beta_1 X + \beta_2 Yt_0$

To estimate the effect size, Hedge's *g* (also known as the corrected effect size) was computed. Hedge's *g* is preferable to Cohen's *d* in the case of small sample sizes (Hedges, 1981; Hedges & Olkin, 1985).

Earlier studies suggest that effect of gamification declines over time during the intervention period (Gremaud et al., 2018; Patel et al., 2019; Thorsteinsen et al., 2014). To examine whether a declining trend was present in this study, the effect of gamification at different timepoints during the intervention period was examined by extending the longitudinal analysis of covariance model to include *Time* as a main effect (fixed variable) and the interaction between *Time* and *Treatment Group* as shown in Equation 2:

Y_t ➔ *Intervention Steps: the mean daily step count during the intervention*

X ➔ *Treatment (0 for control and 1 for gamified treatment)*

Yt_0 ➔ *Baseline Steps: the mean daily step count at baseline*

Time ➔ *Timepoints during the intervention period*

Equation 2*:* $Y_t = \beta_0 + \beta_1 X + \beta_2 Yt_0 + \beta_3 Time + \beta_4 X \times Time$

For the second hypothesis *(H2: Hybrid design expected to facilitate the strongest effect on physical activity*), the effect of each respective treatment group (competition, cooperation, and hybrid) during the intervention was estimated by including *Group* as the treatment variable as shown in Equation 3:

Y_t ➔ *Intervention Steps: the mean daily step count during the intervention*

X ➔ *Treatment Group (control, competition, cooperation, hybrid)*

Yt_0 ➔ *Baseline Steps: the mean daily step count at baseline*

Equation 3*:* $Y_t = \beta_0 + \beta_1 X + \beta_2 Yt_0$

To test the robustness of the findings, the analysis was repeated including gender as a covariate in the models specified above. In addition, for sensitivity analysis, the dataset was also analysed using panel data random effects regression models.

Data analysis of psychological outcomes

Descriptive statistics including means and standard deviation were computed for each experiential outcome for the control and gamified groups. Following that, a Shapiro-Wilk test was conducted to determine whether the score distribution of each construct follows a normal distribution. In the case of a normal distribution, parametric statistical tests are utilised, otherwise when the normality assumption is not satisfied, the non-parametric equivalent tests are performed.

To test the third hypothesis set out for the study (*H3: Gamified groups expected to report higher scores for intrinsic motivation and perceived usefulness than the control group*), an analysis of the differences in the means between the groups was carried out for each construct. A Mann Whitney test (the non-parametric equivalent of the independent t-test) was carried out for each construct to test whether there were significant differences in the means reported between the control and the gamified groups. Furthermore, a Kruskal-Wallis test (the non-parametric equivalent of the one-way ANOVA test) was conducted for each construct to check for any significant differences between the means of each treatment group.

3.5 Research strategy 2: Longitudinal study on subjective well-being

A longitudinal survey study was conducted to gather data to answer the following research question:

> *RQ2: Do experiences of gamification and self-tracking create positive emotional, cognitive, and behavioural responses that yield enhanced well-being?*

3.5.1 Study design and time horizon

This study involved a two-wave longitudinal survey conducted before and after the implementation of a behavioural intervention of physical activity, namely self-tracking of physical activity, alone and in conjunction with gamification. Pre-intervention data was collected in January 2020, followed by a four-week behavioural intervention of physical activity. Then, post-intervention data was collected in March 2020[14] (see Figure 6).

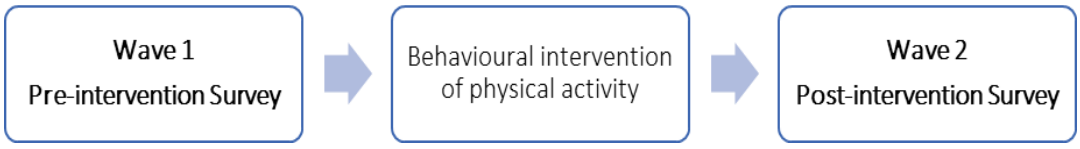

Figure 6: Study timeline

3.5.2 Participants and data collection procedure

All participants recruited for the experimental study (explained in Section 3.4.2) provided voluntary consent to participate in this study which involved completing pre- and post-intervention questionnaires. Data collection for wave 1 and wave 2 was carried out through self-completed pen-and-paper questionnaires. Pre- and post-intervention questionnaires were estimated to take around three and four minutes respectively. In total, 80 participants completed both pre- and post-intervention surveys. In addition to the data gathered through the questionnaires (explained in Section 3.5.3), objective data on physical activity was made available through the physical activity trackers utilised during the experimental study (explained in Section 3.4).

[14] It is essential to note that survey data was gathered prior to the COVID-19 outbreak in Malta. A pandemic situation could have affected individuals' well-being levels.

3.5.3 Questionnaire design

Pre- and post-intervention questionnaires were purposely designed to gather data on subjective well-being, potential correlates of well-being identified in literature (Briguglio, 2019), as well as the users' psychological responses following the behavioural intervention of physical activity. Subjective well-being was measured using two validated items identified in literature (European Social Survey, 2018) namely *life satisfaction* and *happiness* pre-and post-intervention. Data on potential predictors of well-being included demographic and lifestyle variables, as well as self-reported measures of the respondents' level of physical activity. Demographic data was only gathered pre-intervention, while data on well-being measures, lifestyle variables and stage of physical activity was gathered pre- and post-intervention. The post-intervention (wave two) survey also included questions on the emotional and cognitive psychological responses following the intervention. The emotional response was measured in terms of the users' enjoyment and interest (hedonic benefit), while the cognitive response was measured in terms of the perceived usefulness (utilitarian benefit) of the activity (Ryan, 1982). The questionnaire items were developed by adapting existing validated measures from prior literature as described in Table 6. A copy of the questionnaires utilised for wave one (pre-intervention) and wave two (post-intervention) is presented as part of Appendix C.

The behavioural change in physical activity was proxied by two different measures. First, the change in the self-reported measure of the stage of physical activity recorded before and after the behavioural intervention of physical activity (see Table 6). This self-reported measure is based on the stages of change identified in the transtheoretical model of behaviour change (Prochaska & Velicer, 1997). Second, a dummy variable (*PA behaviour change*) recorded the change in physical activity (based on the step counts gathered through physical activity trackers) as either a positive change or a negative change in physical activity behaviour. The latter provides an objective measure of the physical activity behavioural change.

Table 6: Questionnaire items – Well-being outcome measures and potential correlates

Measures	**Source**	**Items**	**Question type**
Life satisfaction	Adapted from European Social Survey (2018)	How satisfied are you with your life nowadays?	11-point likert scale
Happiness	Adapted from European Social Survey (2018)	How happy do you feel at the present moment?	11-point likert scale
Demographic variables	Adapted from Briguglio (2019)	Gender, age group, employment status, weight, height, children under 16 years in their current household, relationship status, sufficient income in the household, and nationality.	Single-code multiple choice questions
Lifestyle variables	Adapted from Briguglio (2019)	Participation in artistic or creative events, religious or spiritual activities, leisure time in nature, time with family and friends, voluntary work, and having a balance between work and 'play'.	Dichotomous questions (Yes/No)
Stage of change of physical activity	Adapted from Prochaska & Velicer (1997) Stages of change model for behaviour change	Participants were asked to choose <u>one</u> option that best describes the current level of physical activity. *Note: Options indicated different stages of physical activity*	Single-code multiple choice question.
Enjoyment and Interest *(Emotional response)*	Adapted from the Interest / Enjoyment sub-scale of the Intrinsic Motivation Inventory (Ryan, 1982)	I enjoyed doing this experience very much This experience was fun to do I thought this was a boring experience (R)	7-point Likert scale anchored 'Not at all true' to Very true'
Perceived Usefulness *(Cognitive response)*	Adapted from the Value / Usefulness sub-scale of the Intrinsic Motivation Inventory (Ryan, 1982)	I believe this experience was of some value to me I think that doing this experience was useful to increase my physical activity I think doing this experience helped me to increase my physical activity	7-point Likert scale anchored 'Not at all true' to Very true'

3.5.4 Pilot study

Prior to launching the fieldwork, a pilot study was carried out with ten individuals to test the proposed data collection tools, including the questionnaires and the process of collecting data through the activity trackers as part of the study. This pilot study involved setting up the activity trackers for participants to use for a period of two weeks and going through the process of

gathering step count data. The pilot test highlighted the importance of synchronising the wearables with the smartphone application. As a result, participants were asked to synchronise the wearables daily every evening to ensure the correct estimate of step counts was measured.

The pilot study also examined whether the questionnaire items were comprehensible and appropriate. The pilot test questionnaire included the International Physical Activity Questionnaire (IPAQ) which was intended to provide a self-reported measure of physical activity based on the recall of the last seven days before participants were assigned a smartwatch. However, the majority of the respondents claimed that they found it challenging to complete the set of questions that provided a self-reported evaluation measure of physical activity. Participants struggled to be able to provide an estimate of the number of hours and minutes they spent doing moderate and vigorous physical activity, and the time spent walking and sitting during the last seven days. Moreover, the inclusion of IPAQ was significantly lengthening the time taken to complete the questionnaire. In view of the accessibility of objective step count data through the wearable devices, the IPAQ items were removed from the actual questionnaire used for this study. To determine the level of physical activity of the participants prior to the study, a self-reported measure of the current stage of physical activity level (see Table 6) was included in the questionnaire instead.

3.5.5 Interventions

Participants were randomly assigned to either a non-gamified (n = 20) or a gamified self-tracking experience (n = 60). Participants were blindly allocated to groups. Each group was colour-coded to hide the identity of each group from participants. During the intervention period, all participants were given a smartwatch (Xiaomi Mi Band) to track their physical activity.[15] During the set-up of the wearables and the corresponding application installed on their smartphones, all participants were allowed to choose a personalised daily step target. Goal setting is a commonly used feature in self-tracking motivational technologies (Aldenaini, Oyebode, et al., 2020) that supports users' intrinsic motivation and self-regulation (Latham & Locke, 1991).

[15] All participants were advised on how to pair and synchronise the smartwatch with the corresponding mobile application, and to wear the device at all times. The battery lasts approximately two weeks. Participants had to charge their wearable device only once during the experiment and were advised to do so during the night.

Participants assigned to the non-gamified self-tracking group monitored whether they achieved their personal daily step goal target set on their smartwatch. In addition to a self-tracking experience, participants assigned to the gamification group were randomly assigned to either a group cooperation challenge, an individual competition, or an inter-team competition. The design of these gamified experiences was guided by the classification of gamification features (Morschheuser et al., 2017) and gamification design frameworks identified in literature (Buckley et al., 2018; Liu et al., 2013). The game elements utilised within these interventions are associated with the motivational constructs of the self-determination theory (Ryan & Deci, 2000b) to afford an appealing and motivating experience for the users (Buckley et al., 2018). The gamification experiences were designed using a gamified platform (pointagram.com) that was accessible to all participants through an application installed on their smartphone or through a web browser. Further details on the design of the gamified experiences together with visual images were presented in Section 3.4.5.

3.5.6 Statistical data analysis

Statistical analysis was carried out in four phases. First, descriptive statistics for the baseline well-being measures and the potential correlates were computed using pre-intervention data. Pairwise correlations were computed for the well-being measures (dependent variables) and their potential correlates. Then, a multivariate linear regression analysis was carried out to estimate the baseline models for *life satisfaction* and *happiness* including the potential predictors of well-being identified in literature (Briguglio, 2019).

Second, descriptive statistics were computed for post-intervention well-being measures. In order to test for variation in well-being measures from pre- to post-intervention, a Wilcoxon signed-rank tests (non-parametric equivalent to a paired sample t-test) was conducted. The result from this test determines whether the increase in life satisfaction and happiness scores at post-intervention was statistically significantly different compared to the pre-intervention scores. The effect size *r* was computed using the Z value resulting from Wilcoxon test and the number of observations in the sample (Rosenthal, 1991). The change in well-being was computed as follows:

Well-being Gain = Well-being Wave 2 (Post) – Well-being Wave 1 (Pre)

To test the fourth hypothesis (H4: *The use of gamification enhances the effect on well-being),* Mann-Whitney U tests were carried out to determine whether the use of gamification led to significantly higher gains in well-being measures. To increase the robustness of the results, an ANCOVA was also carried out to determine whether there is a statistically significant difference in the post-intervention well-being scores between the self-tracking group and the gamified group, after controlling for the pre-intervention well-being scores. Furthermore, since different gamification experiences were involved[16], a Kruskal-Wallis test was conducted to also check for significant differences between the different gamification experiences and the self-tracking experience.

Third, statistical analysis was conducted to determine whether there were significant differences in the emotional, cognitive, and behavioural responses between the self-tracking group and the gamification group. Mann-Whitney U tests were conducted to examine differences between the mean scores reported by the self-tracking group and the gamification group in terms of the emotional, cognitive, and self-reported behavioural responses. A Chi-Square test of independence was conducted to check for significant associations between the positive change reported in physical activity behaviour and the type of group (gamified versus non-gamified self-tracking).

Fourth, statistical analysis was carried out on the gains reported in *happiness* and *life satisfaction* to identify which factors were causing an effect on subjective well-being. Pairwise bivariate correlations were computed to examine whether there is a relationship between well-being gains and the potential predictors of change including the baseline level of well-being itself, the emotional (enjoyment and interest), cognitive (perceived usefulness), behavioural (physical activity) responses and gamification. While correlation analysis provides an insight on the strength of positive or negative associations between these well-being constructs, and between them and their potential predictors of change, it is not possible to parse out the net effect of the latter variables on the dependent measures.

[16] Literature presented in Section 2.2.3 suggests that both competitive and cooperative designs could stimulate motivation and enhance well-being. Thus, H4 examines the data from all the gamified groups (relative to the non-gamified group). Nonetheless, statistical tests were carried out to check for any significant differences in the well-being gains reported between the different gamified intervention groups.

Thus, to test whether the emotional (H5), cognitive (H6) and behavioural (H7) manifestations yielded enhanced well-being, a multi-variate regression analysis on the gain scores was carried out for each well-being outcome (*Happiness* and *Life Satisfaction).* The multi-variate regression analysis examined the contribution of each potential predictor of change. The dependent variable for this analysis was the gain (post - pre) in *life satisfaction* and *happiness*. The independent variables included the emotional (*enjoyment and interest*), cognitive (*perceived usefulness*), behavioural (*physical activity*) measures, a dummy variable for gamification and baseline scores for life satisfaction and happiness. The model for well-being gain is presented below (see Equation 4):

***Equation 4**: $WBGain = \beta_0 + \beta_1 BaselineWB + \beta_2 Enjoyment\_Interest + \beta_3 Perceived\_Usefulness + \beta_4 Physical\ activity + \beta_5 Gamification + \varepsilon$*

WBGain is the gain (post – pre) in the life satisfaction / happiness scores
BaselineWB is the life satisfaction / happiness score at Wave 1 (pre-intervention)
Enjoyment_Interest is emotional psychological measure reflecting the hedonic benefit
PerceivedUsefulness is the cognitive psychological measure reflecting the utilitarian benefit
Phsyical_Activity is the behavioural measure of physical activity proxied by two measures (1 – self-reported change in the stage of physical activity; 2 – change in physical activity behaviour based on step counts)
Gamification is a dummy variable coded 1 for gamified group, 0 for the non-gamified self-tracking group

In order to increase the robustness of findings, ANCOVA multivariate regression models were computed on the post-intervention well-being measures (as dependent variables), controlling for the demographic and lifestyle variables, in addition to the independent variables listed in Equation 4.

Literature identifies various methods for estimating and testing treatment effects in the case of pre-post treatment measurements, including ANCOVA-Post, ANOVA-change scores and linear mixed modelling, which all produce equally unbiased estimates of the treatment effects (Connell et al., 2018; Dimitrov & Rumrill, 2003). Since the dataset on well-being outcomes included pre-post treatment data with no missing observations, ANCOVA-Post and ANOVA-Change (gain scores) regression models were adopted as explained above.

All the analysis was carried out using STATA™ (version 16.1, StataCorp). Regression models were estimated using a robust estimator of variance to allow for better fit to the regression models in the case of the presence of outliers in the data.

3.6 Research strategy 3: Qualitative study on users' experiences

Following the randomised controlled experiment (detailed in Section 3.4), a qualitative corroborative study was conducted to answer the following research question:

RQ3: How do gamified self-tracking experiences foster motivation towards physical activity?

3.6.1 Group discussions and interviews

This study involved the conduct of nine focus group discussions and five one-to-one interviews[17] intended to access rich insight into users' experiences of self-tracking and gamification of physical activity. Focus group discussions, because of the engaging social interaction, help gather qualitative data about personal experiences, whereas one-to-one interviews assist in the corroboration of personal experiences at a deeper level of reflection (Braun et al., 2016).

Participant recruitment involved an email invitation sent to the sample of 80 participants recruited for the randomised controlled experiment. In total, 58 participants (of whom 55% were female) provided informed consent to participate in this study. All participants were unrelated to the researcher. Details about the participants in this study are set out in Table 7 and Table 8. For the purpose of this study, the sample size (n = 58) provided an adequate representation of variation of experiences, perceptions and reflections relating to the phenomenon investigated. As qualitative studies are not intended to generalise to the population, but rather offer an understanding that can be projected to theory, it is worth noting that earlier qualitative studies (Corepal et al., 2018; Kappen et al., 2020; Rapp, 2015) investigating gamification adopted similar or smaller sample sizes.[18]

[17] One-to-one interviews were held with participants who were interested to take part in this qualitative study but could not attend one of the focus group sessions.

[18] For instance, Rapp (2015) study on motivational factors in online gamified applications involved a one-month diary study followed by six focus groups with 36 participants. Corepal et al. (2018) explored the use of gamified interventions amongst adolescents through a longitudinal study involving repeated focus groups at four time-points with a sample of 19 participants. Kappen et al. (2020) conducted repeated interviews over an 8-week period with a sample of 30 participants to study how technology facilitates physical activity among older adults.

Table 7: Sample for qualitative study

	Control	**Gamified**			
	Self-monitoring	Competitive	Cooperative	Hybrid	**Total**
Number of participants	14	15	15	14	58

Table 8: Focus group and interviews details

Data	**Number of participants**	**Gender**	**Type of behavioural change experience**
FG 1	7	Mixed	Self-monitoring experience
FG 2	7	Mixed	
FG 3	4	Mixed	Competitive design
FG 4	8	Mixed	
FG 5	6	Mixed	Cooperative design
FG 6	5	Mixed	
FG 7	4	Males	
FG 8	5	Females	Hybrid design
FG 9	8	Mixed	
Interview 1	1	Male	Self-monitoring experience
Interview 2	1	Female	Competitive design
Interview 3	1	Male	
Interview 4	1	Female	
Interview 5	1	Female	Hybrid design

3.6.2 Data collection procedure

In accordance with participants' consent, all focus group discussions and interviews (held at the University campus in March 2020) were audio-recorded and transcribed.

The discussions and interviews followed a semi-structured approach pursuing an agenda with open-ended questions that related to the:

i. General views on how the experiences of the intervention affected the users and the reasons why;

ii. Users' reaction to each of the elements included in the interventions (positive, neutral, and negative reactions were recorded);

iii. Users' reaction to the different gamified designs; and

iv. Factors that could have improved the experience, and increased users' engagement and motivation towards physical activity.

A copy of the full agenda is set out in Appendix C. The focus group discussions lasted between 60 to 90 minutes each, whereas the one-to-one interviews lasted between 15 to 20 minutes each.

3.6.3 Data analysis

All the transcripts were uploaded to an NVivo™ (QSR International) project and analysed through a reflexive thematic analysis (Braun et al., 2016, 2019; Braun & Clarke, 2006). This qualitative data analysis technique involves six key stages: familiarisation with the content of the dataset (stage 1), followed by a systematic process of coding (stage 2) development of provisional themes (stage 3), reviewing the initial themes against the dataset and the coded data (stage 4), revising and naming of the themes (stage 5), and finally, reporting the findings supported with data extracts (stage 6) (Braun & Clarke, 2006).

A reflexive thematic analysis involves an active and flexible analysis allowing the coding process to evolve by gradual identifying patterns and themes (Braun & Clarke, 2006). At this stage the process followed an approach similar to open coding in grounded theory (Corbin & Strauss, 1990). This approach contrasts other thematic analysis approaches, such as Boyatzis (1998) that rely on structured codebook approaches, where codes and conceptualisations of themes are identified early during the analytic process. Reflexive thematic analysis involved the bracketing (Fischer, 2009) of the researcher's preconceptions and existing ideas that might influence the data analysis due to the researchers' familiarity with the literature in the gamification domain. This reflexivity was achieved by keeping a journal of reflections (also recorded as memos in the same NVivo project) that was coded on the same emerging codes and constructs. A credibility check ensued, wherein the emerging themes and codes were discussed with a colleague who had attended all the focus group sessions and took the role of an observer during the discussions. These discussions confirmed that the analytic output reflects the content and meaning of the discussions (Braun et al., 2019; Elliott et al., 1999).

The tables set out in Appendix E are the result of this reflexive and recursive process, summarising the themes emerging from this study, together with definitions for the codes and extracts from the transcripts. The findings from this study are set out in Section 4.4.

3.7 Ethical considerations

In accordance with the University of Malta guidelines, three ethics applications (Reference numbers: 3829_10122019; 3969_07012020; 4345_20022020) were submitted to the Faculty Research Ethics Committee.

During the design of the studies, care was taken to ensure that participants would not be exposed to any physical harm or discomfort. To prevent harm to participants, all participants were required to complete pre-screening related to any prevailing health conditions like heart conditions, chest pain, bone or joint pain, dizziness, pregnancy, or other medical conditions where doctors would have recommended avoidance of physical activity. In such cases, participants would have automatically become ineligible to participate in this study.

All respondents were informed about the four-week commitment to wear a smartwatch and share the daily step count data, completing surveys before and after their experience as well as share insights about their experience. Participation was voluntary and involved no compensation or incentives to participants. Participants were informed about the right to decline or withdraw from the study anytime. The contact information of the researcher was made available to all participants in case they encounter any issue with their smartwatch device, or if they had any query or difficulty that required clarification. A copy of the invitation to participate in this study, and the information and consent forms are included as part of Appendix B.

To protect participants' privacy and guarantee confidentiality at all stages during this study, a unique reference number was assigned to each participant. This unique reference number was linked to all the data collected from the participants' wearable devices and surveys, rather than using the participants' name. Of all the data generated through the physical activity tracker, only step count data was collected. With the permission of participants, focus groups and interviews were audio-recorded to ensure accuracy in the transcription of the data. All the primary data collected was stored in an encrypted folder and data back-ups were stored on a separate hard drive.

3.8 Validity and reliability

At all stages of the study, objectivity and rigour were kept as guiding principles. This ensured a high level of transparency, trustworthiness, and minimal bias. In the experimental study, randomisation was implemented to prevent selection bias and control for extraneous variables. Introducing a control group ensured an unbiased estimate of the treatment causal effect. To minimise performance bias and maximise the validity of the results, the experiment was single-blinded where participants were unaware of the treatment being implemented.

In the survey study, the questionnaire was carefully designed to avoid ambiguous and complex questions. Self-completed questionnaires were utilised to avoid interviewer bias. Validated scales utilised in previous studies were used to gather the required data that adequately reflects the intended constructs. The constructs' reliability for *Intrinsic Motivation* and *Perceived Usefulness* were measured using Cronbach's alpha (α), composite reliability (CR), and average variance extracted (AVE). All the convergent validity metrics obtained were checked against the thresholds (Cronbach's $\alpha > 0.7$, $CR > 0.7$, and $AVE > 0.5$) suggested in literature (Hair et al., 2010). High construct reliability indicated that internal consistency exists among the scale items used to measure a specific construct (Hair et al., 2010).

In the qualitative study, in order to mitigate participant bias, open-ended questions were worded in a neutral manner, and general questions were asked before specific questions about the motivational affordances implemented. Qualitative data was analysed in an open coding approach, without relying on structured codebooks. Reflexive bracketing, the use of memos to record the researcher's reflections, and the involvement of an external independent colleague during the data collection and analysis helped to minimise bias and subjectivity.

3.9 Methodological strengths and limitations

The adoption of a mixed-methods research approach to examine different aspects related to the same phenomenon is considered as a methodological strength. Given the complexity of the topic in this thesis, adopting solely a quantitative or a qualitative method would have provided a partial understanding on the outcomes emerging from gamification. This thesis utilises objective measures on behavioural effects, quantitative self-reported outcomes on psychological effects, and qualitative data on the users' subjective experiences to provide a comprehensive and holistic understanding on the effect of gamification in the context of physical activity. The behavioural effect of gamification was examined through step count data recorded by physical activity trackers, rather than relying on self-reported measures. This study also involved an active control group using a non-gamified self-tracking experience to isolate the behavioural effect of gamification. Another consideration is that physical activity is more accurately measured having a wearable tracker, rather than relying on the sensor-based technologies of smartphones.

The research design, data collection and data analysis procedures have been discussed in detail to allow replicability in future research. As part of the work carried out for this thesis, a protocol for a parallel four-arm randomised controlled field experiment was purposely designed to investigate the effect of different gamified designs on motivation, perceived usefulness, and behavioural change. The protocol explains the design process of three different gamified interventions in the context of physical activity. It outlines the guidelines, procedures and processes followed during the design of the experiment, the data collection and the data analysis to facilitate replicability for future studies.[19]

The challenges encountered during the study and the methodological limitations are discussed hereunder as these provide avenues that could be mitigated in future research. First, the sample size adopted for the field experiment limits the potential of further sub-groups to test specific game elements and further mechanisms. The calculation of the sample size adopted for this study relies on the expected difference between gamified and non-gamified conditions. The difference in step counts between the different gamified conditions was expected to be much lower than the difference between the gamified and the control group. The sample size utilised for this study does not yield adequate power to detect differences between the different gamified conditions. Having a larger sample size would increase the statistical power, support more covariates in the analysis and enhance the generalisability of the results. Understandably, there are challenges to conduct randomised controlled trials using wearable devices (to achieve objective data) with large sample sizes and longer timeframes.

Second, having a daily step goal (also in the control group) could arguably be considered as a gamification feature. However, goal setting is a standard feature even in the case of basic smartwatches. Thus, participants in the active control group would inevitably be exposed to setting daily step targets as a goal. Having an active control group (using a wearable device) was an important consideration in this study to ensure that the observed effect on step counts is not the result of having a wearable device to monitor physical activity. In the domain of physical activity, goals are commonly integrated along with several other game elements that leverage social influences, such as competition and challenges (Cotton & Patel, 2019; Neupane

[19] The protocol for this experiment has been peer-reviewed and accepted for publication. Details regarding publications related to this thesis are presented in Appendix G.

et al., 2021). Indeed, the three gamified conditions included in the field experiment are social-oriented, include several game elements that are commonly adopted in industry practice (Neupane et al., 2020) and are designed in line with gamification frameworks established in literature (Buckley et al., 2018; Morschheuser et al., 2017).

Third, the survey study gathered well-being data through self-reported measures pre- and post-intervention. In addition, data relating to perceived enjoyment and interest, and perceived usefulness was gathered at the end of the intervention period. By contrast, future work could consider alternative methods of gathering data on these measures more frequently during the intervention period. More granular data would enable researchers to identify any potential variations, trends or patterns over time related to the users' psychological responses and the effect on well-being. With technological advances, real-time customer experience tracking of the users' interactions with gamified systems could capture instantaneous feedback avoiding post-experience surveys which rely on participants' recall.

3.10 Conclusion

This chapter described the research methodology in a systematic manner detailing the research philosophical underpinnings of the study, methodological choice, research strategies, time horizon, data collection procedures and data analytical techniques. An account of the ethical considerations at different stages of the research process, as well as the efforts undertaken to minimise bias and maximise the validity of the results followed. The following chapter presents the findings and results emerging from the data analysis.

4 Results

4.1 Introduction

This chapter presents the findings in relation to each research question and hypothesis set out.

Section 4.2 presents the findings from a four-arm randomised controlled field experiment about the psychological and behavioural outcomes resulting from gamification of physical activity. A panel dataset of step count data was analysed to confirm or reject the following:

> **Hypothesis 1:** Gamification improves physical activity - Gamified groups will report higher step counts than the control group during the intervention period.
>
> **Hypothesis 2:** Hybrid design (competitive-cooperative) will facilitate the strongest effect on physical activity.

Furthermore, subjective data was analysed to test the following hypotheses:

> **Hypothesis 3a:** Gamified groups will report higher intrinsic motivation than the control group.
>
> **Hypothesis 3b:** Gamified groups will report higher perceived usefulness than the control group.

Section 4.3 presents the findings from a two-wave longitudinal survey study about how subjective well-being is influenced by self-tracking of physical activity and gamification. The users' emotional and cognitive psychological responses, as well as the individuals' behavioural change in physical activity were considered to examine the resultant effect on the users' well-being. The analysis tests the following hypothesis:

> **Hypothesis 4:** The use of gamification enhances the effect on well-being (relative to a non-gamified self-tracking experience).
>
> **Hypothesis 5**: Enjoyment and interest enhance well-being gain (*Enjoyment and Interest* reflect the users' emotional / affective response to the intervention based on the hedonic benefit of the experience)

Hypothesis 6: Perceived usefulness of the experience enhances well-being gain (*Perceived Usefulness* reflects the users' cognitive response to the intervention based on the utilitarian benefit of the experience)

Hypothesis 7: A positive change in physical activity behaviour enhances well-being gain (*Physical activity* is a behavioural outcome measure that is expected to enhance well-being).

Finally, Section 4.4 presents the findings from the qualitative study that was conducted following the implementation of gamified interventions of physical activity to provide insights on how gamification and self-tracking of physical activity foster motivation towards physical activity.

4.2 Results from the randomised controlled experiment on the effect of gamification on behavioural and psychological outcomes

4.2.1 Sample characteristics

Eighty participants completed the pre-screening criteria and provided voluntary informed consent for participation. All randomised participants completed the four-week study without any withdrawals. The participant flow diagram based on CONSORT guidelines for transparent reporting of randomised trials is presented in Figure 7.

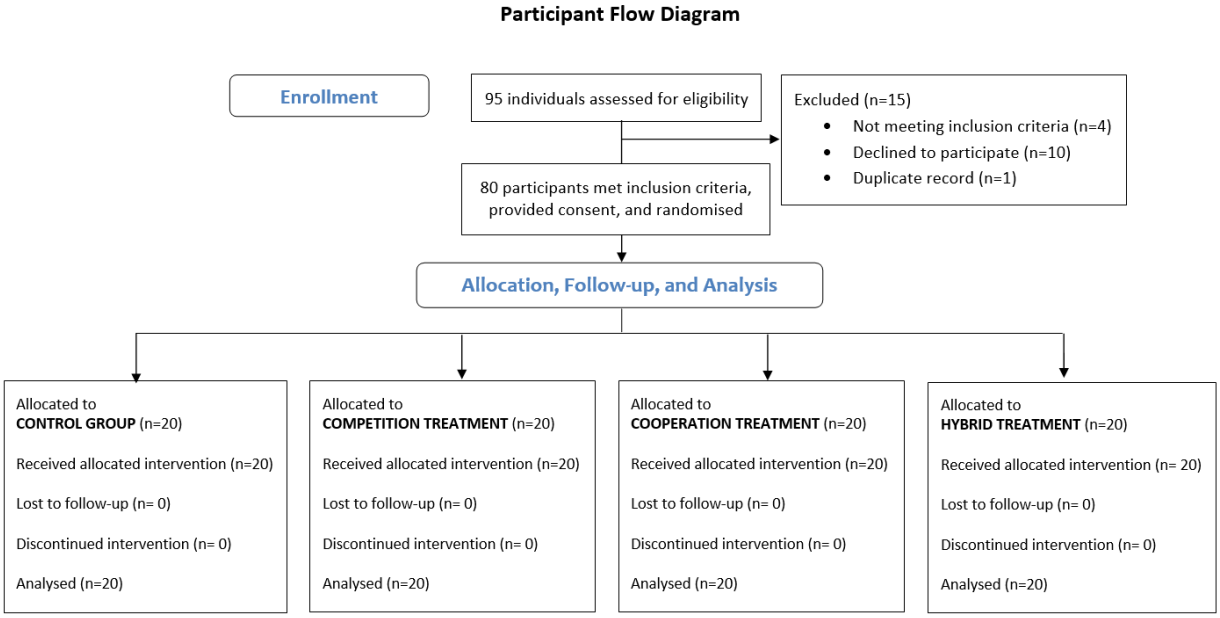

Figure 7: Participant flow diagram

Baseline participants' demographic characteristics and pre-intervention physical activity levels are presented in Table 9. These descriptive results summarise the frequencies and respective percentages for categorical variables, and the means and standard deviation for continuous variables for each respective group. The p-values presented are the results of the Chi-Square tests for categorical variables and independent t-tests for continuous variables carried out to check for significant differences between the groups.

Out of 80 participants, 56% (n = 45) were female, 52% (n = 42) were young adults (20 - 34 years), while 45% (n = 36) were middle-aged (35 – 54 years), 76% (n = 61) were Maltese, and 65% (n = 52) were in full-time employment. The participants' average BMI was 25.3. The distribution between the control and the gamified groups was relatively well-balanced in terms of all the demographic variables, with the exception of having less participants in the control

group who had children under the age of sixteen, even though randomisation was employed. The distribution of participants between the groups was relatively well-balanced in terms of physical activity level at baseline, suggesting a balanced mix of participants ranging from a sedentary or low activity lifestyle to a highly active lifestyle. The classification of the baseline step counts into physical activity levels ranging from a sedentary lifestyle to a highly active lifestyle is based on established pedometer-determined physical activity levels identified in literature (Tudor-Locke & Bassett, 2004).

Table 9: Sample characteristics for control versus gamification group

Sample characteristics	**Control Group**	**Gamification Group**	**p value**
Gender, n (%)			
Male	11 (55.0%)	24 (40.0%)	0.24
Female	9 (45.0%)	36 (60.0%)	
Age Groups, n (%)			
Young adulthood (20 - 34 years)	13 (65.0%)	29 (48.3%)	
Middle aged (35 - 54 years)	7 (35.0%)	29 (48.3%)	0.36
Older adulthood (55+ years)	0 (0%)	2 (3.3%)	
Nationality, n (%)			
Maltese	15 (75.0%)	46 (76.7%)	0.88
Non-Maltese	5 (25.0%)	14 (23.3%)	
Employment Status, n (%)			
Full-time employed	14 (70.0%)	38 (63.3%)	0.59
Part-time employed	4 (20.0%)	13 (21.7%)	0.88
Full-time student	7 (35.0%)	20 (33.3%)	0.89
Part-time student	8 (40.0%)	18 (30.0%)	0.41
Have children under 16 years, n (%)	1 (5.0%)	17 (28.3%)	0.03*
Have a steady relationship, n (%)	13 (65.0%)	45 (75.0%)	0.39
Have sufficient income, n (%) *(see note)*	18 (90.0%)	52 (88.1%)	0.82
BMI Pre Intervention, mean (SD)	26.59 (4.23)	24.80 (4.69)	0.13
Familiarity with technology, mean (SD)	5.30 (1.92)	5.65 (1.40)	0.46
Baseline level of physical activity, n (%)			
Sedentary lifestyle (<5,000 steps/day)	2 (10.0%)	11 (18.3%)	
Low active (=> 5,000 and <7,500 steps/day)	7 (35.0%)	17 (28.3%)	
Somewhat active (=>7,500 and <10,000 steps/day)	7 (35.0%)	15 (25.0%)	0.48
Active lifestyle (=>10,000 and <12,500 steps/day)	1 (5.0%)	11 (18.3%)	
Highly active lifestyle (=>12,500 steps/day)	3 (15.0%)	6 (10.0%)	

* Indicates significant difference between groups.

Notes: N= 80; 1 respondent provided no data to the question related to income.

4.2.2 Behavioural outcome

Hypothesis 1: Gamification improves physical activity - Gamified groups expected to report higher step counts than the control group during the intervention period.

The mean (SD) baseline daily step count for the control group was 8557 (SD = 2916), and 8243 (SD = 3837) for the gamified groups. Differences in baseline levels between the groups following randomisation are due to chance (Roberts & Torgerson, 1999). Nonetheless, an independent t-test on these baseline levels confirms that there were no statistical differences in the mean daily step counts of the control and the gamified groups (t(78) = 0.334; p = 0.739).

During the intervention period, the mean daily step count of the gamified groups increased, whilst that of the control group declined (Figure 8). The result from the longitudinal data analysis of covariance shows that gamification resulted in a positive effect on the daily step count (adjusted difference from control = 811; 95% CI = 57 to 1565; p = 0.035) supporting Hypothesis H1 (Table 10). The effect size of 0.25 is interpreted as a small effect (Ellis, 2010; Hedges & Olkin, 1985; Lenhard & Lenhard, 2016).

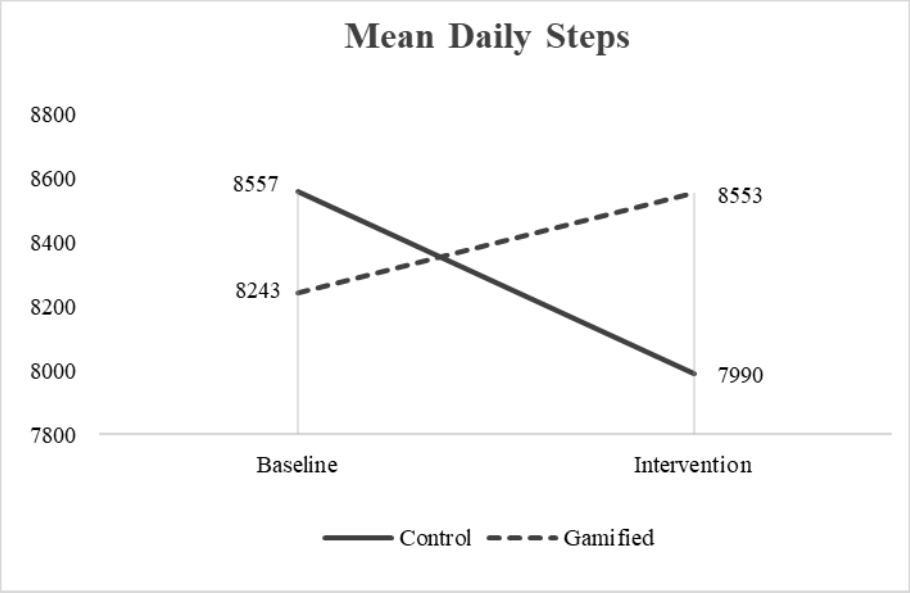

Figure 8: Mean daily step count at baseline versus intervention period

Table 10: Gamification effect on mean daily step count

Timepoint	Control Mean (SD)	Gamified Mean (SD)	Overall treatment effect: Adjusted between-groups difference (95% CI)	p-value	Hedge's g
Baseline	8557 (2916)	8243 (3837)	811 (57 to 1565)	0.035	0.25
Intervention	7990 (2146)	8553 (3690)			

To increase the robustness of the findings, the analysis was repeated including gender as a covariate in the model. The results remain unchanged; gamification increased the mean daily step count (adjusted difference from control = 772 steps; 95% CI= 17 to 1528; p = 0.045) and gender was not a significant covariate (p = 0.482). Supporting tables are presented in Appendix D.

Analysing the step counts at different timepoints during the intervention period, both the control and the gamified groups exhibit a similar progressive decay in the mean daily steps during the intervention period (see Figure 9). In the absence of gamification, there is a statistically significant decline of 1055 steps in the control group by the end of the intervention (t(19) = -2.674, p = 0.015, Hedge's g = 0.37). The mean daily step count of the control group decreased week after week ending at 87.7% of their baseline level by the end of the study.

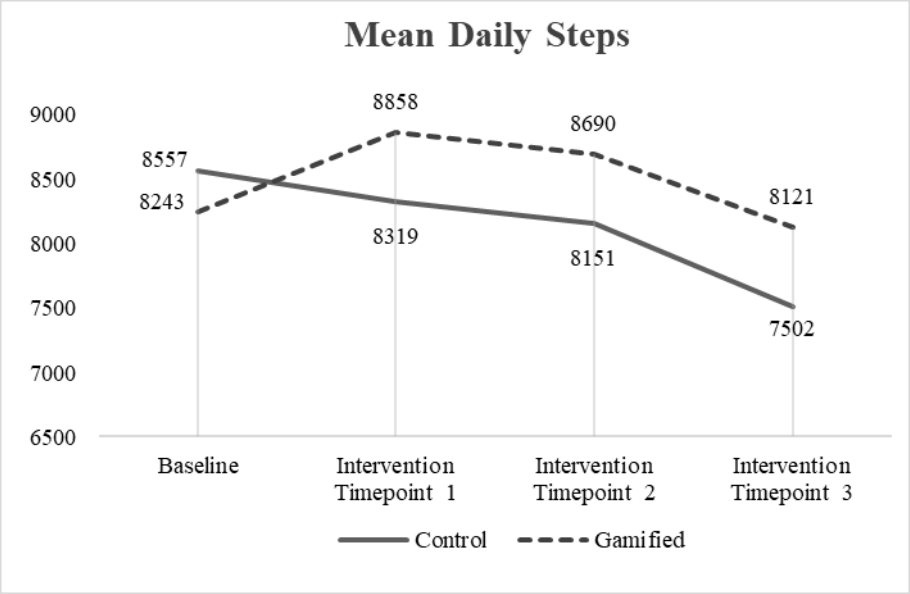

Figure 9: Mean daily steps at different timepoints

Over the course of the intervention, both groups experienced a decline in the physical activity recorded (decline in step count over time = 408 steps; 95% CI= -756 to -60; p = 0.022). However, notwithstanding the progressive decay in the physical activity levels during the intervention period, the relative advantage of the gamified groups in comparison to the control group is sustained throughout the intervention period (Figure 9). Participants in the gamified group did 839 more steps per day compared to those in the control group by the end of the intervention (adjusted difference from control = 839, 95% CI = 4 to 1673, p = 0.049, Hedge's

g = 0.28). This provides further evidence that there is potential to leverage gamification to increase physical activity and that the relative advantage is sustained in the short-term.

Hypothesis 2: Hybrid design will facilitate the strongest effect on physical activity.

In order to estimate which gamification design was the most effective at increasing physical activity, the effect of each gamified design (competitive, cooperative and hybrid designs) was analysed. Baseline participants' characteristics in terms of the demographic characteristics and pre-intervention physical activity levels for each treatment group versus the control group are set out in Table 11. The p-values presented are the results of the Chi-Square tests for categorical variables, and ANOVA tests for continuous variables carried out to check for significant differences between the groups. When comparing the distribution of participants across all sub-groups, there was a gender imbalance (more females in the competitive and hybrid groups). Nonetheless, gender did not prove to be significantly different when comparing the control versus the gamified groups (see Table 9).

At baseline all groups had a mean daily step count in the range of 7600 to 8950 daily steps. The mean baseline daily steps (SD) were 8557 (SD = 2916) for the control group, 8202 (SD = 3512) for the cooperation group, 7608 (SD = 3123) for the hybrid group and 8920 (SD = 4766) for the competition group. To assess for significant differences between the groups in the baseline step counts, a one-way ANOVA test was carried out. The result shows that there were no statistically significant differences in the baseline step counts ($F(3,76) = 0.469$, $p = 0.705$).

As set out in Figure 10, during the intervention period, the mean daily step count of all the gamified groups increased, whilst that of the control group declined. The results from the longitudinal analysis of covariance shows that the hybrid gamified group was the most effective at increasing physical activity (adjusted difference from control = 981 steps; 95% CI= -45 to 2008; p = 0.061), supporting Hypothesis 2: Hybrid design will facilitate the strongest effect on physical activity (Table 12). The increase in physical activity is significant for the hybrid and competitive gamified groups at 0.1 level of significance. The hybrid gamified design, in which participants were involved in an inter-team competition had the strongest effect (Hedge's g = 0.39). Smaller effects were reported for the pure competitive (Hedge's g = 0.23) and pure cooperative (Hedge's g = 0.23) gamified designs.

To increase the robustness of the findings, the analysis was repeated including gender as a covariate in the model. The hybrid design was still the most effective gamification design (adjusted difference from control = 928 steps; 95% CI= -86 to 1943; p = 0.073), and gender was not a significant covariate (p = 0.540). Supporting tables are presented in Appendix D.

For sensitivity analysis, the data was analysis using panel data random effects regression models and evidence showing that the results remain unchanged is presented in Appendix D.

Table 11: Sample characteristics for each treatment group

Demographic characteristics	**Control Group** (n=20)	**Competition Group** (n=20)	**Cooperation Group** (n=20)	**Hybrid Group** (n=20)	**p value**
Gender, n (%)					
Male	11 (55.0%)	5 (25.0%)	13 (65.0%)	6 (30.0%)	0.03*
Female	9 (45.0%)	15 (75.0%)	7 (35.0%)	14 (70.0%)	
Age Groups, n (%)					
Young adulthood (20 - 34 years)	13 (65.0%)	6 (30.0%)	11 (55.0%)	12 (60.0%)	
Middle aged (35 - 54 years)	7 (35.0%)	13 (65.0%)	8 (40.0%)	8 (40.0%)	0.30
Older adulthood (55+ years)	0 (0%)	1 (5.0%)	1 (5.0%)	0 (0%)	
Nationality, n (%)					
Maltese	15 (75.0%)	14 (70.0%)	16 (80.0%)	16 (80.0%)	0.86
Non-Maltese	5 (25.0%)	6 (30.0%)	4 (20.0%)	4 (20.0%)	
Employment Status, n (%)					
Full-time employed	14 (70.0%)	10 (50.0%)	12 (60.0%)	16 (80.0%)	0.22
Part-time employed	4 (20.0%)	4 (20.0%)	5 (25.0%)	4 (20.0%)	0.97
Full-time student	7 (35.0%)	6 (30.0%)	8 (40.0%)	6 (30.0%)	0.89
Part-time student	8 (40.0%)	4 (20.0%)	7 (35.0%)	7 (35.0%)	0.56
Have children under 16 years, n (%)	1 (5.0%)	6 (30%)	7 (35.0%)	4 (20%)	0.11
Have a steady relationship, n (%)	13 (65.0%)	15 (75.0%)	15 (75.0%)	15 (75.0%)	0.86
Have sufficient income, n (%)	18 (90.0%)	17 (89.5%)	17 (89.5%)	18 (90.0%)	0.95
BMI Pre Study, mean (SD)	26.59 (4.23)	24.44 (5.42)	25.20 (3.48)	24.76 (5.15)	0.48
Familiarity with technology, mean (SD)	5.30 (1.92)	5.35 (1.66)	5.85 (1.46)	5.75 (1.02)	0.59
Baseline level of physical activity, n (%)					
Sedentary lifestyle (<5,000 steps/day)	2 (10.0%)	3 (15.0%)	4 (20.0%)	4 (20.0%)	
Low active (=> 5,000 and <7,500 steps/day)	7 (35.0%)	6 (30.0%)	5 (25.0%)	6 (30.0%)	
Somewhat active (=>7,500 and <10,000 steps/day)	7 (35.0%)	4 (20.0%)	4 (20.0%)	7 (35.0%)	0.83
Active lifestyle (=>10,000 and <12,500 steps/day)	1 (5.0%)	4 (20.0%)	5 (25.0%)	2 (10.0%)	
Highly active lifestyle (=>12,500 steps/day)	3 (15.0%)	3 (15.0%)	2 (10.0%)	1 (5.0%)	

* Indicates significant differences between groups.

Notes: N= 80; 1 respondent provided no data to the question related to income.

Table 12: Effect of different gamification designs on the mean daily step count

Timepoint	Control	Competition	Cooperation	Hybrid
	mean (SD)	mean (SD)	mean (SD)	mean (SD)
Baseline	8557 (2916)	8920 (4766)	8202 (3512)	7608 (3123)
Intervention	7990 (2146)	9115 (4449)	8340 (3391)	8203 (3238)
Adjusted difference from control		817	637	981
95% CI		-138 to 1772	-328 to 1602	-45 to 2008
p value		0.094	0.196	0.061
Hedge's g		0.23	0.23	0.39

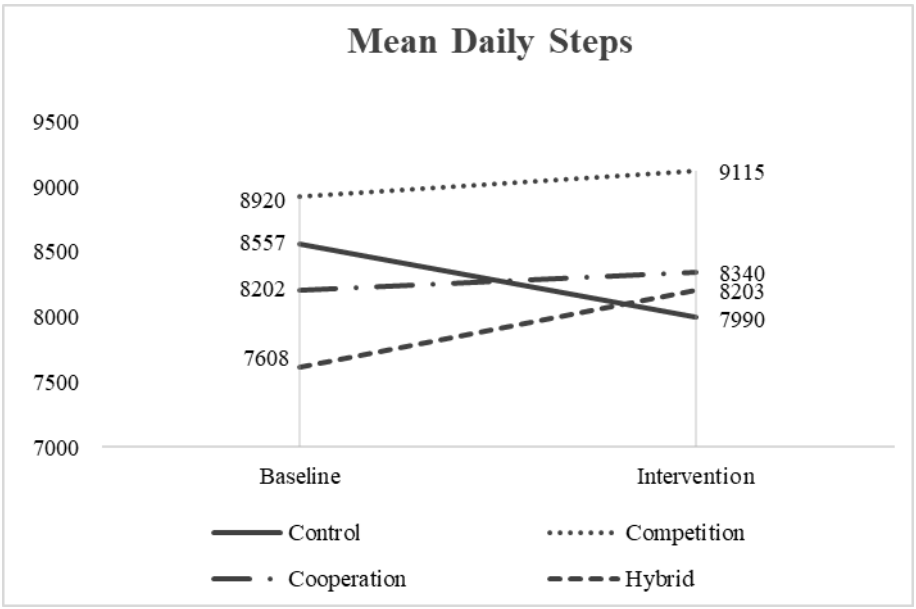

Figure 10: Mean daily step count for each treatment group

4.2.3 Psychological outcomes

This study measured the participants' *intrinsic motivation* and *perceived usefulness* of the experience as psychological outcomes resulting from gamification of physical activity. Each construct subscale was found to be reliable, indicating internal consistency among the scale items used to measure each specific construct. Intrinsic Motivation subscale ($\alpha = 0.735$; CR = 0.859; AVE = 0.677) resulted in a scale with M = 6.22 and SD = 0.867, and the Perceived Usefulness subscale ($\alpha = 0.808$; CR = 0.891; AVE = 0.734) resulted in a scale with M = 5.46 and SD = 1.288. The descriptive statistics including the means and the standard deviation for

both constructs are presented in Table 13. As observed in the results below (see Figures 11 and 12), both the control and the gamified group reported similar positive experiential outcomes.

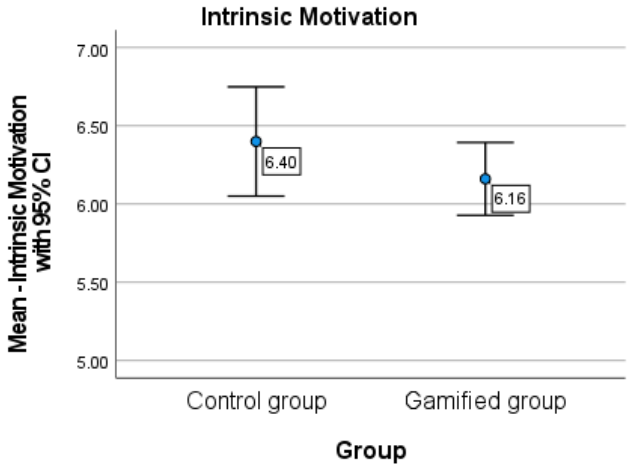

Figure 11: Error bar chart for intrinsic motivation (control versus gamified group)

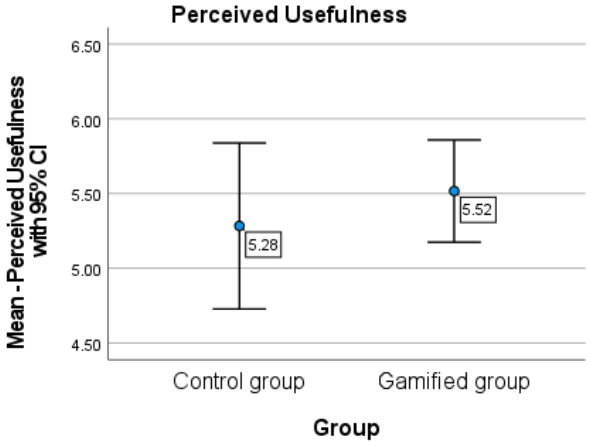

Figure 12: Error bar chart for perceived usefulness (control versus gamified group)

Table 13: Means and standard deviation for users' intrinsic motivation and perceived usefulness (control versus gamified group)

	Intrinsic Motivation		Perceived Usefulness	
Group	**Mean**	**SD**	**Mean**	**SD**
Gamified	6.16	0.901	5.52	1.324
Control	6.40	0.746	5.28	1.186

A Shapiro-Wilk test was conducted to determine whether the score distribution of each construct follows a normal distribution. As presented in Table 14, the score distributions do not follow the normal distribution, thus non-parametric inferential statistical tests were appropriate. The Mann-Whitney test (non-parametric equivalent to an independent t-test) was conducted to determine whether there are significant differences between the scores reported by the control group and the gamified group in terms of the experiential outcomes.

Table 14: Shapiro-Wilk test result for intrinsic motivation and perceived usefulness constructs

	Shapiro-Wilk		
Variable	**Statistic**	**Df**	**Sig.**
Intrinsic Motivation	0.838	80	<.001
Perceived Usefulness	0.920	80	<.001

The analysis revealed no statistically significant differences between the control group and the gamified group in intrinsic motivation scores (U = 513.50, z = -0.988, p = 0.323) and perceived usefulness scores (U = 509.00, z = -1.017, p = 0.309). Therefore, both Hypothesis 3a and Hypothesis 3b listed below are rejected.

H3a: Gamified groups will report higher intrinsic motivation than the control group.

H3b: Gamified groups will report higher perceived usefulness than the control group

Furthermore, the descriptive statistics for both experiential outcome constructs for each treatment group were computed (Table 15). A Kruskal-Wallis H test (non-parametric equivalent to the one-way ANOVA test) was conducted to determine if there were statistically significant differences between the groups in terms of intrinsic motivation and perceived usefulness. The analysis revealed no statistically significant differences between the groups for both Intrinsic Motivation ($\chi^2(3) = 1.160, p = 0.657$), and Perceived Usefulness ($\chi^2(3) = 1.969, p = 0.579$).

Table 15: Means and standard deviation for users' intrinsic motivation and perceived usefulness (control versus different treatment groups)

	Intrinsic Motivation		Perceived Usefulness	
Group	**Mean**	**SD**	**Mean**	**SD**
Control	6.40	0.746	5.28	1.186
Cooperation	6.08	0.910	5.47	1.126
Hybrid	6.25	0.830	5.68	1.348
Competition	6.15	0.994	5.40	1.520

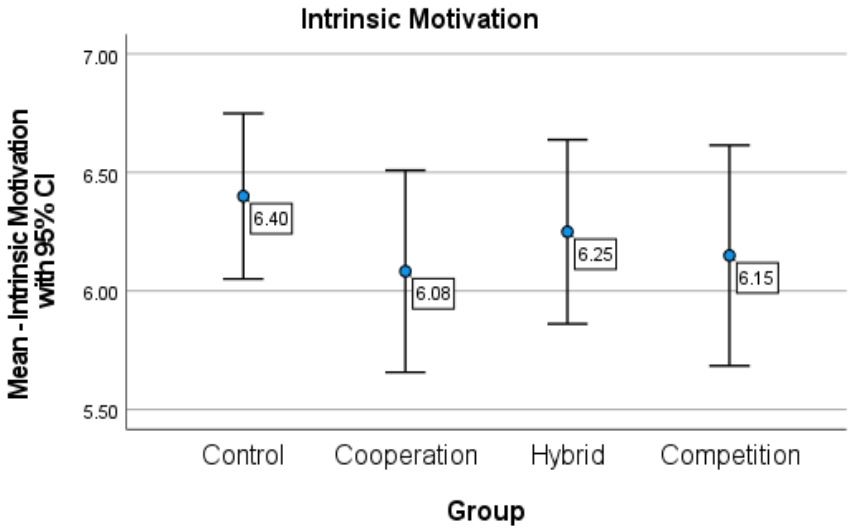

Figure 13: Error bar chart - intrinsic motivation (control versus different treatment groups)

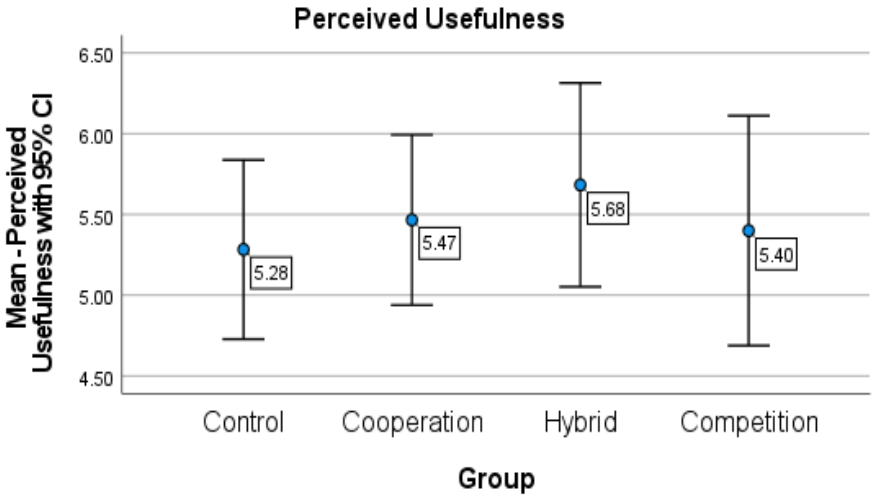

Figure 14: Error bar chart - perceived usefulness (control versus different treatment groups)

4.3 Results from the longitudinal study on subjective well-being

4.3.1 Sample characteristics

Descriptive statistics for the sample characteristics, including demographic and lifestyle data, and the self-reported stage of physical activity at baseline (pre-intervention) are presented in Table 16.

Table 16: Sample characteristics of participants at baseline

Variable	Description	n	%
Male	Male gender	35	44%
Female	Female gender	45	56%
YoungAdult	Age group - Young adulthood (20 - 34 years)	42	52%
MiddleAged	Age group - Middle aged (35 - 54 years)	36	45%
Older	Age group - Older adulthood (55+ years)	2	3%
Maltese	Maltese nationality	61	76%
EmployedFT	Full-time employed	52	65%
EmployedPT	Part-time employed	17	21%
StudentFT	Full-time student	27	34%
StudentPT	Part-time student	26	33%
Children	Have children under 16 years	18	23%
Relationship	Have a steady relationship	58	73%
Income	Have sufficient income	70*	89%
VoluntaryWork	Do voluntary work	19	24%
ReligiousActivity	Participate in religious/ spiritual activity	25	31%
CreativeActivity	Participate in artistic/ creative activity	16	20%
Time_Nature	Spend time in nature	49	61%
Time_FF	Spend time with friends & family	77	96%
BalanceWorkPlay	Maintain a balance between ‘work’ and ‘play’	40	50%
PA _Precontemplation	Currently do not exercise, and do not intend to start exercising in the next 6 months	5	6%
PA_Contemplation	Currently do not exercise, but I am thinking about starting exercise in the next 6 months	27	34%
PA_Preparation	Currently exercise some, but not regularly	28	35%
PA_Action	Currently exercise regularly	20	25%

*Note: N = 80. PA = Physical activity stage. *1 respondent provided no data to this question.*

Chi-square tests indicate there were no significant differences in the demographic and lifestyle characteristics of the self-tracking and the gamification groups, with the exception of having

less participants in the self-tracking group who had children under the age of sixteen, even though randomisation was employed (see Table 17).[20]

Table 17: Sample characteristics of participants at baseline (self-tracking versus gamification group)

Sample characteristics	Self-Tracking Group	Gamification Group	p value
Gender			
Male, n (%)	11 (55.0%)	24 (40.0%)	0.24
Female, n (%)	9 (45.0%)	36 (60.0%)	
Age Groups			
Young adulthood (20 - 34 years)	13 (65.0%)	29 (48.3%)	
Middle aged (35 - 54 years)	7 (35.0%)	29 (48.3%)	0.36
Older adulthood (55+ years)	0 (0%)	2 (3.3%)	
Nationality			
Maltese, n (%)	15 (75.0%)	46 (76.7%)	0.88
Non-Maltese, n (%)	5 (25.0%)	14 (23.3%)	
Employment Status			
Full-time employed, n (%)	14 (70.0%)	38 (63.3%)	0.59
Part-time employed, n (%)	4 (20.0%)	13 (21.7%)	0.88
Full-time student, n (%)	7 (35.0%)	20 (33.3%)	0.89
Part-time student, n (%)	8 (40.0%)	18 (30.0%)	0.41
Have children under 16 years, n (%)	1 (5.0%)	17 (28.3%)	0.03*
Have a steady relationship, n (%)	13 (65.0%)	45 (75.0%)	0.39
Have sufficient income, n (%) *(see note)*	18 (90.0%)	52 (88.1%)	0.82
Self-reported stage of physical activity			
Precontemplation stage, n (%)	0 (0.0%)	5 (8.3%)	
Contemplation stage, n (%)	6 (30.0%)	21 (35.0%)	0.29
Preparation stage, n (%)	10 (50.0%)	18 (30.0%)	
Action Stage, n (%)	4 (20.0%)	16 (26.7%)	
Do voluntary work, n (%)	5 (25.0%)	14 (23.3%)	0.88
Participate in **religious/ spiritual activity**, n (%)	5 (25.0%)	20 (33.3%)	0.49
Participate in **artistic/ creative activity**, n (%)	4 (20.0%)	12 (20.0%)	1.00
Spend **time in nature**, n (%)	12 (60.0%)	37 (61.7%)	0.90
Spend **time with friends & family**, n (%)	19 (95.0%)	58 (96.7%)	0.73
Get **enough rest and sleep**, n (%)	14 (70.0%)	37 (61.7%)	0.50
Maintain a **balance between 'work' and 'play'**, n (%)	11 (55.0%)	29 (49.3%)	0.61

* Indicates significant differences between groups. Note: N=80. 1 respondent provided no data to the question related to income

[20] For sensitivity analysis, 'having children under 16 years of age' was included as a covariate amongst other variables in the multi-variate regression model analysing the potential predictors of well-being change. The results (Section 4.3.5) confirm that having children under 16 years of age was not a significant predictor to the change reported in the well-being measures.

4.3.2 Baseline well-being

The descriptive statistics for well-being measures at baseline are presented in Table 18. The mean (SD) baseline subjective well-being scores were 6.86 (SD = 1.941) for life satisfaction and 6.90 (SD =1.769) for happiness.

Table 18: Descriptive statistics for well-being measures at baseline

Variable	n	Mean	SD	Min	Max
Life Satisfaction	80	6.86	1.941	0	10
Happiness	80	6.90	1.769	0	10

Table 19 presents the pairwise correlations for *Happiness* and *Life Satisfaction.* As anticipated, there is a strong positive correlation between them. Both show a low positive correlation with spending time in nature, spending time with family and friends, and having a balance between work and play. The results also indicate that there is an association with physical activity; positive with regular exercise and negative with the pre-contemplation stage of physical activity - those who currently do not exercise, and do not intend to start exercising in the near future.

Table 19: Pairwise correlations for happiness and life satisfaction

Variables	Happiness	Life Satisfaction
Happiness	1.000	**.836*** **
Life Satisfaction	**.836*** **	1.000
VoluntaryWork	0.060	0.102
ReligiousActivity	0.080	0.104
CreativeActivity	-0.062	-0.111
Time_Nature	**0.215***	**.301*** **
Time_FF	**0.211***	**0.200***
BalanceWorkPlay	**.374*** **	**.314*** **
PA_ Pre-contemplation	**-0.193***	**-0.198***
PA_Contemplation	-0.001	0.002
PA_Preparation	0.103	**.239** **
PA_Action	-0.004	-0.155
Male	0.086	0.128
YoungAdult	0.104	0.102
Maltese	0.072	0.067
EmployedFT	-0.177	-0.146
Children	**-0.200***	-0.158
Relationship	0.130	**0.195***
Income	0.011	0.014

*Note: *** p < 0.01 ** p < 0.05 * p < 0.1.*

Table 20 presents the size, direction, and the level of significance of the coefficients for each of the variables examined in relation to *happiness* and *life satisfaction.* The intercept indicates that when all the variables examined in this model are zero, the mean value of happiness is approximately 3.3 and life satisfaction is approximately 2.3. Significant predictors of happiness include participation in religious activity (β = 0.704), time with family and friends (β = 2.531), having a balance between work and play (β = 1.136), full time employment (β = -0.883) and having children under the age of sixteen (β = -1.035). The multivariate regression model significantly predicted happiness, $F(15,63) = 3.30$, $p < 0.001$, R-squared = 0.360. Similarly, significant predictors of life satisfaction include participation in religious activity (β = 0.777), time in nature (β =0.784), time with family and friends (β =2.052), having a balance between work and play (β = 1.150), participation in physical exercise (β = 0.848); and full-time employment (β = -0.882). The multivariate regression model significantly predicted life satisfaction, $F(15,63) = 9.39$, $p < 0.001$, R-squared = 0.390.

Table 20: Happiness and life satisfaction regression models (pre-intervention)

VARIABLES	**Happiness model**	**Life satisfaction model**
VoluntaryWork	-0.216 (0.455)	-0.112 (0.536)
ReligiousActivity	0.704* (0.400)	0.777* (0.438)
CreativeActivity	-0.202 (0.551)	-0.488 (0.566)
Time_Nature	0.389 (0.375)	0.784** (0.380)
Time_FF	2.531*** (0.680)	2.052*** (0.513)
BalanceWorkPlay	1.136*** (0.364)	1.150*** (0.424)
PA_ Pre-contemplation	-0.163 (0.940)	0.335 (1.082)
PA_Contemplation	0.011 (0.467)	0.367 (0.471)
PA_Preparation	0.104 (0.428)	0.848* (0.503)
Male	0.282 (0.396)	0.620 (0.427)
YoungAdult	-0.093 (0.408)	0.026 (0.458)
EmployedFT	-0.883** (0.399)	-0.882** (0.422)
Children	-1.035* (0.567)	-0.615 (0.611)
Relationship	0.662 (0.442)	0.738 (0.446)
Income	0.560 (0.699)	0.927 (0.850)
Constant	3.265*** (1.020)	2.346** (1.041)
Observations	79	79
R-squared	0.360	0.390

Notes: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

4.3.3 Change in well-being: pre- versus post-intervention

The results (see Table 21 and Figure 15) revealed a significant increase in *happiness* (z = -2.298, p = 0.022, effect size r = -0.182) and *life satisfaction* (z = -2.911, p = 0.004, effect size r = -0.230) when comparing pre-intervention versus post-intervention well-being scores.

Table 21: Pre- and post-intervention well-being scores

	Pre-Intervention		Post-Intervention		Gain (post - pre)	
Variable	**M**	**SD**	**M**	**SD**	**M**	**SD**
Happiness	6.90	1.769	7.21	1.998	0.31	1.688
Life Satisfaction	6.86	1.941	7.34	1.916	0.48	1.467

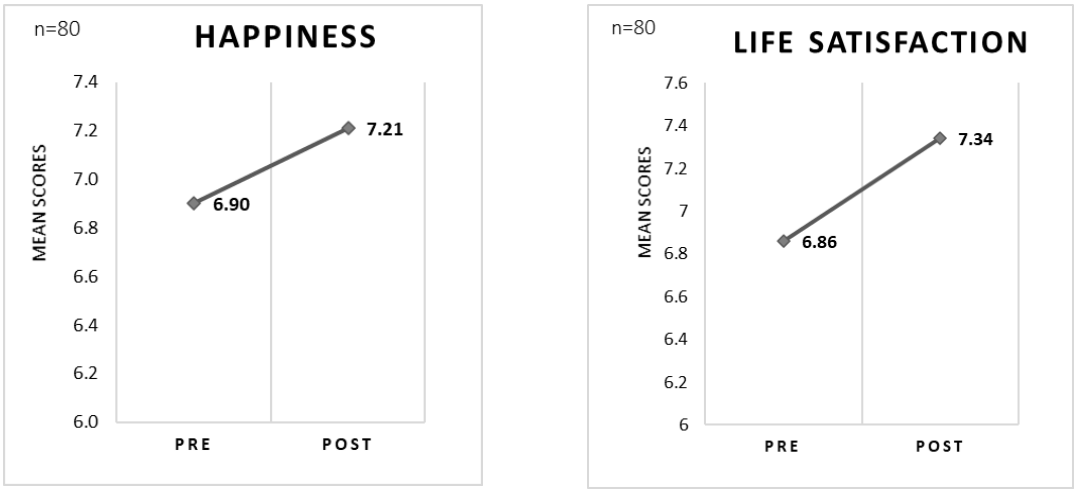

Figure 15: Happiness and life satisfaction (pre- and post-intervention means)

Pre- and post-intervention well-being scores for the gamification group in comparison to the non-gamified self-tracking group are presented in Table 22. A Mann Whitney U Test was carried out to check for significant differences between the groups in the pre-intervention scores. Prior to the intervention, there were no statistical differences between the control and the gamified groups in life satisfaction scores (U = 524.5, z = -0.852, p = 0.394) and happiness scores (U = 519.0, z = -0.921, p = 0.357). The self-tracking and gamification groups reported similar increases in well-being measures (see Table 22). The findings show that the use of gamification did not produce significantly higher gains in *happiness* (U = 587.5; z = -0.143, p = 0.886) and *life satisfaction* (U = 529.0; z = -0.816, p = 0.414) relative to a non-gamified self-tracking experience, thus **rejecting Hypothesis 4** (*H4: The use of gamification enhances the effect on well-being relative to a non-gamified self-tracking experience).*

Table 22: Pre- and post-intervention well-being scores for gamified and non-gamified groups

	PRE		POST		Gain (post -pre)	
LIFE SATISFACTION	M	SD	M	SD	M	SD
Gamified	6.83	1.833	7.35	1.812	0.52	1.321
Non-gamified	6.95	2.282	7.30	2.250	0.35	1.872
HAPPINESS	M	SD	M	SD	M	SD
Gamified	6.88	1.637	7.18	1.873	0.30	1.629
Non-gamified	6.95	2.164	7.30	2.386	0.35	1.899

Figure 16: Happiness and life satisfaction (pre- and post-intervention means - self-tracking group versus gamification group)

ANCOVA results also show that after adjusting for the pre-test well-being scores, there are no statistically significant differences in the post-intervention well-being scores between the self-tracking group and the gamified group for *happiness* ($F(1,77) = 0.029$, $p = 0.865$) and *life satisfaction* ($F(1,77) = 0.140$, $p = 0.709$). Standardised residuals for the interventions were normally distributed, as assessed by Shapiro-Wilk's tests ($p > 0.05$). The assumption for homogeneity of regression slopes was satisfied since the interaction term was not statistically significant (Life Satisfaction: $F(1,76) = 0.218$ $p = 0.642$; and Happiness: $F(1,76) = 0.088$ $p = 0.768$). There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p = 0.515$ for Happiness) and ($p = 0.258$ for Life Satisfaction).

Furthermore, statistical tests were also conducted to check whether there were any significant differences between the different types of gamified experiences and the non-gamified self-

tracking experience.[21] ANCOVA results show that after controlling for pre-intervention well-being scores, there are no significant differences in the post-intervention well-being scores of the different gamified experiences and the non-gamified self-tracking group for happiness ($F(3,75) = 0.750$, $p = 0.526$) and *life satisfaction* ($F(3,75) = 0.183$, $p = 0.908$). Results from Kruskal-Wallis tests confirm there were no significant differences in the gains reported for *happiness* ($\chi^2(3) = 1.944$, $p = 0.584$) and *life satisfaction* ($\chi^2(3) = 3.066$, $p = 0.381$) between the different types of gamified experiences and non-gamified self-tracking experience.

4.3.4 Emotional, cognitive and behavioural responses

The scales used to measure the users' *emotional* and *cognitive* responses were found to be reliable, indicating internal consistency among the scale items used to measure each specific construct. *Enjoyment and Interest* sub-scale ($\alpha = .735$; CR = 0.859; AVE = 0.677) resulted in a scale with M = 6.22 and SD = 0.867, and the *Perceived Usefulness* sub-scale ($\alpha = .808$; CR = 0.891; AVE = 0.734) resulted in a scale with M = 5.46 and SD = 1.288. Both the non-gamified and the gamified self-tracking groups reported similar positive psychological outcomes (see Table 23). Results show that there are no significant differences between the non-gamified and gamified self-tracking groups in terms of reported *enjoyment and interest* ($U = 513.50$, $z = -0.988$, $p = 0.323$) and *perceived usefulness* ($U = 509.00$, $z = -1.017$, $p = 0.309$). Furthermore, Kruskal-Wallis test results also confirms that there are no significant differences in *enjoyment and interest* ($\chi^2(3) = 1.160$, $p = 0.657$), and *perceived usefulness* ($\chi^2(3) = 1.969$, $p = 0.579$) between the different types of gamification and the non-gamified self-tracking experience.

Table 23: Users' emotional and cognitive responses

	Enjoyment & Interest	**Perceived Usefulness**
Group	Mean (SD)	Mean (SD)
Self-Tracking	6.40 (0.746)	5.28 (1.186)
Gamification	6.16 (0.901)	5.52 (1.324)

The *behavioural* response was proxied by two measures reflecting the change in physical activity (see Table 24). First, the change in the self-reported stage of physical activity. Second, the change in physical activity behaviour was categorised as either a positive or a negative change reflecting an increase or decrease in the step counts respectively. No significant

[21] Supplementary table presenting the pre- and post-intervention well-being scores for each gamified group is set out in Appendix D: Supplementary material for quantitative results.

differences were found between the gamified and non-gamified self-tracking group in the self-reported change in the physical activity stage (U = 563.0, z = -0.509, p = 0.611). By contrast, there was a statistically significant association between the group and the change in physical activity behaviour when using the objective measures based on the step count data gathered through the wearable devices, ($\chi 2(1) = 5.414$, p = 0.02). The findings show there is a significant association between the gamified groups and a positive behavioural change in physical activity. This result corroborates the findings (presented in Section 4.2) on the effect of gamification on physical activity behavioural outcomes.[22] Both the self-reported and objective measures of physical activity behaviour change were included in subsequent analysis to determine whether either the self-reported measures or objective measures relating to the change in physical activity were linked to the increase in well-being measures.

Table 24: Users' behavioural responses

Group	**Change in the self-reported stage of physical activity**	**Number of participants who had a positive change in steps**
	Mean (SD)	n (%)
Non-gamified	0.00 (0.562)	5 (25%)
Gamified	0.10 (0.630)	33 (55%)

4.3.5 Predictors of well-being change

This section examines the potential predictors for the gains reported in well-being measures. These include: 1) the emotional response to the intervention measured in terms of enjoyment and interest; 2) the cognitive response to the intervention measured in terms of perceived usefulness; 3) the behavioural response to the intervention proxied by two measures: change in the self-reported stage of physical activity and change in physical activity behaviour based on the step counts; 4) the use of gamification; and 5) baseline well-being levels for happiness and life satisfaction.

The correlations between the gains reported in well-being outcomes and the potential variables causing an increase in subjective well-being are set out in Table 25.

[22] The findings indicated that gamification increased the mean daily step count relative to a non-gamified self-tracking experience (adjusted difference from control = 811; 95% CI = 57 to 1565; p = 0.035).

Table 25: Correlations for well-being gains and potential predictors of change

Correlations									
Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. Happiness Gain	--								
2. Life satisfaction Gain	**.691****	--							
3. Baseline Happiness	**-.333****	**-.323****	--						
4. Baseline Life Satisfaction	-0.184	**-.395****	**.881****	--					
5. Enjoyment Interest	**.393****	**.428****	0.015	0.041	--				
6. Perceived Usefulness	**.321****	**.482****	0.076	0.083	**.696****	--			
7. Change in PA stage	-0.023	0.002	-0.040	-0.077	0.008	0.095	--		
8. Change in PA behaviour	0.032	-0.018	0.068	0.029	-0.147	-0.086	-0.035	--	
9. Gamification	-0.013	0.050	-0.016	-0.026	-0.120	0.079	0.071	**.260***	--

*** Correlation is significant at the 0.01 level (2-tailed).*

The correlations indicate a significant positive correlation between happiness gain and life satisfaction gain, a significant negative correlation with the baseline happiness and life satisfaction scores, and a significant positive association with the users' enjoyment and interest, and perceived usefulness. Furthermore, there is a significant positive correlation between the increase in physical activity behaviour and the use of gamification.

The results (see Table 26) of the multivariate regression analysis on the well-being gains provide evidence to the hypotheses set out for this study.

The emotional psychological response to the intervention measured through the individuals' *enjoyment and interest* (hedonic benefit) produced a significant positive effect ($\beta = 0.604$) that increased the individuals' happiness levels, **supporting Hypothesis 5** *(H5: Enjoyment and interest enhance well-being gain)*

The cognitive psychological response to the intervention measured through the *perceived usefulness* (utilitarian benefit) produced a significant positive effect ($\beta = 0.466$) that increased the individuals' life satisfaction levels, **supporting Hypothesis 6** *(H6: Perceived usefulness of the experience enhances well-being gain).*

The subjective and objective measures reflecting the change in physical activity over the course of the intervention period were not significant predictors to the gains reported in happiness and life satisfaction scores, thus **rejecting Hypothesis 7** *(H7: A positive change in physical activity behaviour enhances well-being gain).*

The use of gamification did not produce a significant positive effect on well-being, thus providing further evidence to **reject Hypothesis 4** *(H4: The use of gamification enhances the effect on well-being).*

Table 26: Regression results – Determinants of happiness gain and life satisfaction gain

Variables	**Happiness Gain**	**Life Satisfaction Gain**
Baseline Happiness	**-0.343*** (0.113)**	
Baseline Life Satisfaction		**-0.334*** (0.085)**
Enjoyment Interest	**0.604** (0.271)**	0.289 (0.213)
Perceived Usefulness	0.196 (0.181)	**0.466*** (0.142)**
Change in PA stage (self-reported)	-0.134 (0.251)	-0.172 (0.262)
Change in PA behaviour	0.398 (0.373)	0.140 (0.292)
Gamification	-0.080 (0.464)	0.063 (0.404)
Constant	-2.270 (1.571)	-1.675 (1.399)
Observations	80	80
R-squared	0.295	0.445
F value	F(6, 73) = 4.52	F(6, 73) = 6.78
P value	p < 0.001	p < 0.001

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results also provide evidence that the baseline measure of happiness was a significant predictor to the happiness gain (β = -0.343). The negative coefficient value for baseline happiness indicates that lower happiness levels at baseline contributed to higher happiness gains. Similarly, the baseline measure of life satisfaction was a significant predictor to the gain reported in life satisfaction (β = -0.334), meaning that lower life satisfaction levels at baseline contributed to higher life satisfaction gains.

To increase the robustness of our findings, a multivariate regression analysis was carried out on the post well-being measures, while controlling for the demographic and lifestyle variables. The results remain unchanged (see Table 27).

Table 27: Full regression model for well-being outcomes

Variables	Happiness model	Life Satisfaction model
Baseline Happiness	**0.676***** (0.161)	
Baseline Life Satisfaction		**0.750***** (0.094)
Enjoyment & Interest	**0.718**** (0.337)	0.343 (0.213)
Perceived Usefulness	0.136 (0.243)	**0.537***** (0.178)
Change in PA stage	-0.230 (0.294)	-0.232 (0.271)
Change in PA behaviour	0.385 (0.352)	0.285 (0.296)
Gamification	-0.033 (0.447)	0.041 (0.403)
Male Gender	0.085 (0.382)	0.047 (0.339)
Young Adult	-0.239 (0.369)	-0.387 (0.311)
Children under 16 years	-0.335 (0.754)	-0.349 (0.458)
Voluntary work	-0.195 (0.379)	0.081 (0.257)
Religious activity	0.094 (0.455)	-0.461 (0.300)
Artistic activity	-0.348 (0.610)	-0.147 (0.351)
Spends time in nature	-0.160 (0.390)	-0.458 (0.316)
Spends time with family & friends	1.072 (1.193)	0.167 (0.601)
Balance work and play	-0.457 (0.358)	**-0.556**** (0.241)
Regular physical activity	0.053 (0.455)	0.335 (0.336)
Constant	-3.269 (1.979)	**-2.296*** (1.262)
Observations	80	80
R-squared	0.533	0.727

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

To summarise, the results show that both the gamified and the non-gamified self-tracking experiences reported similar emotional and cognitive psychological responses, and similar changes in the self-reported stage of physical activity. While self-reported measures of physical activity indicate no differences between the groups, objective measures confirm that there was indeed a significant positive association between the use of gamification and the positive change recorded in physical activity behaviour. Both the gamified group and the non-gamified self-tracking experiences report similar increases in well-being outcome measures post-intervention. The use of gamification did not produce significantly higher gains in happiness and life satisfaction relative to a non-gamified self-tracking experience (rejecting Hypothesis H4). The users' perceived usefulness of the experiences was associated with an increase in the individuals' life satisfaction, while enjoyment and interest were linked to an increase in the individuals' happiness (accepting both Hypotheses H5 and H6). However, the change in physical activity behaviour was not linked to the increase in well-being (rejecting Hypothesis H7).

4.4 Qualitative findings from users' experiences on gamifying physical activity: A thematic analysis

The analysis of qualitative data moved from initial familiarisation with the data set, followed by the generation of the initial codes in a systematic and thorough manner across the entire dataset. This was followed by the collation and examination of all the codes and the generation of provisional themes. Subsequently, the emergent themes were reviewed and refined for *internal homogeneity* and *external heterogeneity* (Patton, 1990). As a last step, coded extracts of data were checked to ensure that they are coherent with the themes identified.

The thematic analysis resulted in three main themes, namely 1) the self-monitoring of physical activity; 2) the motivational elements encouraging physical activity; and 3) the value of social engagement and group cohesion. The thematic map presented in Figure 17 illustrates the main themes and the respective sub-themes.

Thematic Map

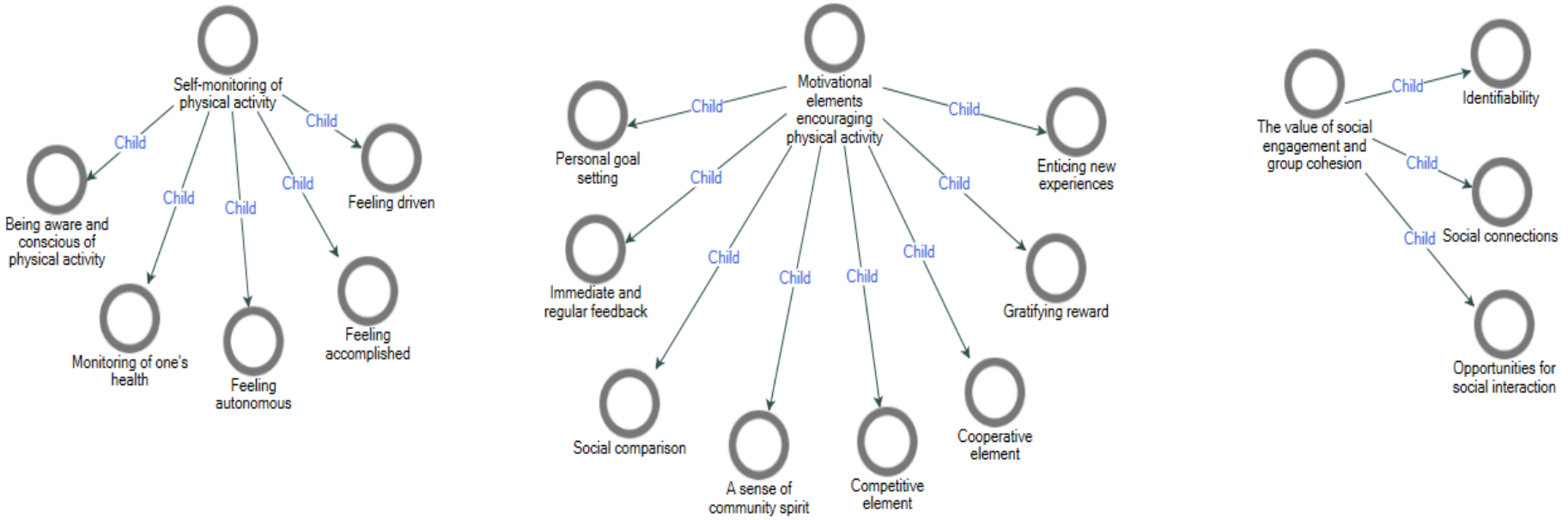

Figure 17: Thematic map showing the main themes and sub-themes from the qualitative analysis

4.4.1 Theme 1: Self-monitoring of physical activity

This theme relates to the users' perceptions and feelings of monitoring one's physical activity using a wearable physical activity tracker. The data suggests that participants from all the different groups expressed similar positive reactions towards self-monitoring of physical activity. The five sub-themes that emerged under this theme are discussed in relation to the participants' experiences from the different groups collectively.

4.4.1.1 Being aware and conscious of physical activity

As a result of using a wearable physical activity tracker, all participants agreed that they were more aware and conscious of their level of physical activity. Gaining self-knowledge was regarded as a positive, interesting, and enjoyable experience. Participants became aware of their average daily number of steps, identified patterns of physical activity or inactivity during the weekdays and weekends, and were conscious about their level of physical activity during work, hobbies, and sports activities.

> *"It was a positive experience to see when I am sedentary… and how to alter small things in my routine to be more active." (Competition group, female)*

> *"…what I've realised is the lack of physical activity in general that I carry out" (Cooperation group, male)*

> *"Within the same day I realised that I walk much more in the morning and then barely walk in the afternoon or the evening, and then the other way round for the weekends..." (Competition group, male)*

Moreover, real-time personal informatics facilitated self-reflection on the level of physical activity undertaken and led individuals to reconsider their lifestyle and behaviours.

> *"What I liked is that at the end of the day, I could see my activity and reflect on it. For instance, one time I was at work, I did a whole day non-stop working and only did 3K steps, while on another day I felt relaxed at home and did my hobbies, and I did 10/11K steps. I became more conscious" (Hybrid group, female)*

> *"You can track your performance and reflect on your behaviour. For example, I felt good today, let me see what I did today…" (Competition group, male)*

> *"I became more mindful … Doing that little bit extra that you normally wouldn't." (Control group, female)*

4.4.1.2 Monitoring one's health

Participants consistently perceived positively their own self-monitoring of health using a wearable device. Participants were aware that apart from physical activity, they could also monitor other health related issues. The benefits which participants deemed useful include step count tracking, regular reminders from the smartwatch to move and avoid staying idle, monitoring of heart rate, identifying sleep patterns (deep sleep versus light sleep) and sleep quality. Participants also remarked on the advantage of more accuracy when compared to self-tracking through a smartphone application. Several participants indicated that a long-lasting battery life of approximately two weeks was convenient, and they intend to continue using a smartwatch in the future.

> *"…to have a healthy balance, sleep is where I would start, and it was good to monitor it." (Cooperation group, male)*

> *"I will get a smartwatch to monitor my steps, and even for the heartbeat it's quite interesting to monitor when I'm nervous or when I'm calm." (Hybrid group, male)*

> *"It made me aware of not getting enough rest." (Competition group, female)*

4.4.1.3 Feeling autonomous

Gaining knowledge on one's own performance results in feelings of autonomy. Participants felt empowered with the real-time data that they gained from the quantified-self experience. A self-tracking experience helped participants monitor and adapt their behaviour to improve their health outlook. As participants articulated:

> *"If you're a target-oriented person, it affects you positively... it [personal informatics] gives you control" (Competition group, male).*

> *"…I'm taking care of my health…that is good." (Hybrid group, female)*

Participants across all groups were primarily interested in setting and achieving their own personal goals. Personalised targets and self-competition enabled participants to be autonomous and challenge themselves to achieve higher physical activity, irrespective of the group performance. Whilst the smartwatch mobile application suggested a daily target of 8,000 steps, participants were free to set their own targets and goals. Feelings of determination to achieve the individuals' target were expressed by most of the participants. The ability to customise their own individual targets fostered autonomy and avoided negative emotional responses, such as feelings of guilt when a target is not

achieved or feelings of pressure to achieve the stipulated targets. Some of the participants intentionally set a low target to feel more in control and avoid potential negative emotions.

> *"I set the daily target as a bare minimum not to feel guilty, 3K and that's it… I always achieved it, 3K is a very small number, then over and above was extra bonus for me." (Cooperation group, male)*

> *"I hate having a daily target because I felt it limits my freedom, so I decreased it to a low number and the psychology of that worked for me … and I hit 20K steps a day" (Cooperation group, female)*

4.4.1.4 Feeling accomplished

Participants felt positive emotions during the self-tracking experience, which some described as the feel-good factor of achievement. These feelings relate to a sense of pride and satisfaction after seeing progress and/or accomplishments. Participants commonly associated feelings of accomplishment to two specific instances during the self-tracking experience of physical activity: i) when participants achieved the daily step count target or a high step count as a milestone; and ii) when participants felt the smartwatch vibrate upon reaching the daily step goal.

> *"When the watch vibrates / buzzes when I hit the target, I was like ... YES! I reached my target today... that gave me that good feeling…" (Cooperation group, female)*

> *"I was reaching my target of step counts quite quicker than I thought…it was a pleasant surprise." (Control group, female)*

> *"I was very competitive with myself, as soon as I did 20K, I said: OK I did it! ... It was like I wanted to prove to myself that I could do it." (Hybrid group, female)*

> *"…it was rewarding to see I exceed the target." (Competition group, male)*

The language used, as well as the non-verbal communication by some of the participants highlighted the strength of the emotions felt related to the sense of accomplishment. For instance, one participant said: *"I've beaten my target …" (Cooperation group, male).*

4.4.1.5 Feeling driven

Participants consistently remarked that self-tracking fostered a drive to become more active. Several individuals were consciously adapting their daily routines, such as taking the stairs instead of the lift, parking the car further away from the office, taking short breaks to move more and use the car less. Monitoring their physical activity encouraged most participants to engage in healthy lifestyle habits and instil a positive outlook towards fitness.

"When I started this [experience], I was motivated to exercise more… You are motivated because you are monitoring (Cooperation group, female)

"It was a good experience, it pushed me enough to start dedicating some hours to me... tomorrow I'll start Pilates" (Competition group, female)

"…If I see I only did 5000 steps, then I would go for a longer walk with my dog in the evening…" (Hybrid group, female)

"… the fact that I was monitoring my activity made me very aware, it did push me to take action..." (Competition group, Female)

"It [the smartwatch] does affect, for example, when I was at work, there were instances I was checking how many steps I made, then I say maybe I walk a bit more even to get the documents myself." (Control group, male)

Furthermore, seeing their progression and achievements, participants were motivated to challenge themselves to reach higher daily step counts.

"…I was targeting to increase the steps of the previous day everyday…" (Competition group, female)

"…as soon as I reached the goal, I say how much further I can push myself 1K or 2K…competition with myself." (Control group, female)

Actively monitoring one's physical activity also had a positive influence on others with whom participants had a close social connection. Participants expressed positive emotional responses, such as enjoyment, fun and contentment when others showed interest and engaged in physical activity. Family members and friends were inspired and motivated to also engage in physical activity.

"Something that I also enjoyed it was good fun when I was with friends, it influenced others, friends used to ask me: how many steps did we do?" (Competition group, female)

"I tried to involve the whole family to walk more, I encouraged my son to remove the tablet and come walking with me to walk more to get the treasure. It was a nice idea." (Cooperation group, female)

"I noticed that the experience did not only affect me because I had the kids watching me saying let me see how much you did. It also influenced my kids as well, the kids were more motivated to come out walking..." (Competition group, female)

4.4.2 Theme 2: Motivational elements encouraging physical activity

This theme relates to the elements that motivated participants to engage in physical activity. Participants had different self-tracking experiences, alone and in conjunction with gamification; hence this section will highlight any differences between the groups revealed during the data analysis. The eight sub-themes that emerged under this theme are discussed in relation to the participants' experiences and include both positive and negative reactions.

4.4.2.1 Personal goal setting

Setting personal goals was seen as a prominent positive influence on physical activity. Achieving personal targets was an intrinsically motivating and rewarding experience among participants, leading to feelings of autonomy and competence. To avoid a situation that could result in negative psychological responses, some participants explained that they decided to set a target that they considered as very low. Most of the participants indicated that if they did not manage to achieve the personal target, it was not perceived as a case of failure, and it did not result in negative feelings.

> *"It was rewarding to see that I exceed the target." (Competition group, male)*

> *"It was a positive experience I realised I was reaching my target of step counts quite quicker than I thought." (Control group, female)*

> *"If I didn't manage to hit the target I didn't feel that I did not do something that I should have done…most of my steps were over 10K." (Cooperation group, male)*

Personal targets led to self-competition. This was particularly evident in the gamified groups, which provided an opportunity for individuals to challenge themselves and make a conscious effort to achieve the target. Overall, participants in the gamified groups pushed harder to reach the target compared to those who were doing a non-gamified self-monitoring experience. Most of the participants in the non-gamified self-tracking group were not as engaged to achieve the personal target.

> *"When I go home, I look at the watch I'd see I did 8/9K... I didn't make my 10K, so let's take the dogs out for a walk [laughing], so I reach the bare minimum, it became unacceptable for me to sleep at night without doing those 10Ksteps" Cooperation group male)*

> *"When I set a target of 8000 steps, I remember I had to go to pick up my son, and until I wait for him, I used to walk, 10pm at night and I'm walking around the neighbourhood area, dark and cold until the smartwatch vibrates meaning that I reached my target, then I went to my car (smiling)! (Competition group, female)*

"I kept looking at the step count, for e.g., I see 1 have 1000 more [steps] to go, once to reach the target I was even reading walking around the room rather than sitting down, just to reach my daily target." (Hybrid group, female)

"The fact that I had a threshold [target], I did make it a point to exceed the target by the end of the day. If I go out, I try to reach the target, if I stay at home, I don't because I wouldn't reach my target" (Control group, male)

"I had the target at 8K, one day I had 7980 steps, and then I just gone to sleep …didn't try to do 20 more steps to reach the target." (Control group, male)

Most participants in a group setting were keen on setting their own personal step goal targets, irrespective of others' performance. Personal targets were prioritised over the group goals and shared targets. For instance, when participants had group targets, individuals were more interested in achieving their own personal targets rather than focusing on group goals.

"I think the most thing that influenced me was the daily step goal (target)… as long as I was achieving my target, I felt satisfied" (Hybrid group, female)

I was more interested in trying to achieve the target and improving my physical activity rather than doing to get points." (Cooperation group, male)

"I'm competitive against myself in general… I set my own personal goals, if my next goal was to get the next badge, I'll go for that" (Competition group, female)

Moreover, the motivational effect of step count goals (target) depends on the individuals' personality traits. Individuals who do not consider themselves to be goal-oriented expressed neutral reactions towards having a daily personal target.

4.4.2.2 Immediate and regular feedback

Participants sought immediate and regular feedback on their progress and achievements. Feedback offered a validation of the efforts done and encouraged individuals to strive for more achievements. One participant articulated that technology facilitates *"a kind of return loop that gives you feedback" (Competition group, male).* Participants indicated that they prefer positive and instantaneous feedback on their progress or achievements because this contributes to feelings of competence.

Participants (from all groups) identified the wearable device as the main source of such feedback. Pedometer real-time data encouraged individuals to try to increase their step count. The majority of the participants showed enthusiasm and excitement about the buzzing feeling (vibration) they felt on their smartwatch when they reached their daily

target. Some participants indicated that the buzzing notification from the smartwatch was like a reward, that contributed to mental satisfaction. In the gamified group, some participants remarked that immediate feedback is appreciated and valued more than other elements, such as points, progress bars and badges.

> *"It's very nice to have it buzz / vibrate …getting a badge every day is boring, getting the buzz on your hand is exciting." (Hybrid group, male)*

> *"If the app had to give say: well done, you achieved 8K steps! That [immediate feedback] would be more satisfactory than a badge." (Hybrid group, female)*

> *"When the watch vibrates / buzzes when I hit the target, I was like ... YES! I reached my target today... that gave me that good feeling…" (Cooperation group, female)*

Participants indicated that they would have appreciated more feedback from the mobile application. Participants' suggestions include notifications when the target is achieved for a consecutive number of days, encouraging messages on their progression indicating the number of steps for the next milestone, recommendations to increase the daily target and reminders to engage in physical activity.

> *"…receiving constant feedback on our progress would have helped, it would have made me more engaged (Cooperation group, male)*

> *"I would appreciate more notifications / immediate feedback" (Hybrid group, female)*

> *"For me it would be useful if I reach 8K, then after some time the app could ask or remind me to go to another goal." (Hybrid group, female)*

4.4.2.3 Social comparison

Participants who had a non-gamified self-tracking experience (control group), that did not involve any social comparison features with other members from the same group expressed their interest in seeing others' performance. Some participants from this group tried monitoring and comparing their performance with people they know, such as family members and friends. Participants indicated that seeing others' performance would have made it more interesting and motivating than doing it on their own.

From the gamified groups, social comparison happened mostly in the Competition and the Hybrid groups. Both groups were of a competitive nature and had a leaderboard as one of the game elements. The competitive spirit led to more interest in seeing others' performance as opposed to the Cooperation group. As one participant articulated, the

frame of mind of how individuals look at others' performance changes depending on whether the experience is of a cooperative or competitive nature.

> *"I was happy to see someone doing so well because it was for the team, I thought it was cool, maybe if it was a competition that I could have won something I would have felt different about it." (Cooperation group, male)*

> *"Once you start seeing the performance of others, it became more interesting" (Hybrid group, female)*

Most participants who had an individual competition remarked that they used to check the leaderboard ranking regularly. Comparing one's progress against others and seeing progression of their ranking on the leaderboard was motivating to the majority of the participants.

> *"Being target oriented and a competitive person, I have something to benchmark with, it tends to get me motivated seeing who is behind you or in front of you." (Competition group, male)*

> *"I realised I'm a really competitive person, because the final result per day and per week were really something special for me, I tried to not over push myself, but to force myself to make more steps to reach someone who was in front of me." (Competition group, female)*

> *"I'm competitive really, I saw R001[participant URN] made the maximum step count 31K. I thought to myself I cannot reach him in [the weekly] total, but maybe I can reach him on one day. So, one day I was out… just calculating to at least on one day I achieve that" (Competition group, female)*

While the leaderboard provided motivation to most participants, some participants lost interest in competing when they saw other participants with high step counts. Participants indicated that they would prefer to be in a group with other participants who have similar levels of physical activity, lifestyles, and backgrounds.

4.4.2.4 A sense of community spirit

Most participants found **a team experience** more engaging and motivating than an individual experience.[23] The majority of those having an individual self-monitoring experience expressed their preference to share the experience with others.

> *"If we were in a team, it would have helped" (Control group, female)*

Despite having a group experience, participants from all the three different gamified groups felt that the team spirit was lacking to a certain extent due to the anonymity and

[23] This study involved three different socially oriented gamified experiences where participants were part of a group involving either: i) an individual competition (Competition group); ii) a group challenge (Cooperation group) and iii) an inter-team competition (Hybrid group).

lack of social bonds with others. Consequently, this hampered both competitive and cooperative efforts. The **sense of community spirit** amongst the group members emerged as a determining factor that fosters motivation amongst the team players.

> *"If it wasn't anonymous, it would be different, I didn't know people in my group but if it would be a group with my friends, for one common goal, the chance is higher that we all work together." (Hybrid group, female)*

> *"If you know who the people are, it makes you more competitive, the fact that it is virtual and you don't know who is behind each code doesn't seem very much like a competition" (Competition group, male)*

> *"The fact that we were all anonymous and we didn't really know each other took away from the competitiveness or the buzz of the game... the fact that you don't know the teammates and opponents, it does make the competition aspect less effective." (Hybrid group, male)*

> *"If there was group cohesion, we would have tried more to reach the target." (Cooperation group, male)*

Most participants preferred to have this experience with people with whom they shared a social bond, such as family members, friends, or colleagues. Pre-existing social connections enhance community spirit and strengthen both competitive and collaborative experiences. Some participants were interested in contacting others or sending comments on others' performance through the gamified application, but felt awkward doing so, since the participants did not know each other.

The value of social engagement and group cohesion emerged as a main theme in this analysis. Factors facilitating and hindering social engagement and group cohesion are discussed in Section 4.4.3.

4.4.2.5 Competitive element

The study included two gamified group experiences that had an element of competition: i) an individual competition (Competition group); ii) an inter-team competition (Hybrid group). Participants in competitive settings were regularly comparing their performance with that of others through their ranking on the leaderboard. The leaderboard was one of the game elements commonly mentioned that provoked feelings of progression, achievement, and satisfaction. Some participants indicated that they felt satisfied with their performance even though they did not rank high on the leaderboard, because they acknowledge the limitations that they have in terms of the time available for physical activity.

Participants involved in an individual competition between the group members expressed feelings of accomplishment more frequently than participants in a team competition.

> *"When I saw myself at the beginning at the 18th and at the end 7th, I felt proud of myself" (Competition group, female)*

> *"I used to check others' performance out of curiosity, I used to enjoy I did double the steps of others (all participants laughing)" (Competition group, male)*

> *"At some point I was 18th then I ended up 8th getting higher on the leaderbaord was an achievement in itself" (Competition group, female)*

While the majority of participants indicated that an element of competitiveness provided a stimulating experience to increase physical activity, some participants complained about the diversity in the level of physical activity amongst the group members. Two participants who were taking part in the individual competition (Competition group) had a highly active lifestyle and used to exercise regularly (achieving on average 20K steps daily). Thus, some participants from the same group felt that *"they could not compete"* because those high levels of physical activity were unachievable for them. Participants would have been more motivated if all individuals have similar levels of physical activity. Nevertheless, some participants indicated that they were still motivated to compete and were satisfied with their current level of physical activity.

> *"My competition was with the one below me or very close… (Competition group, female)*

> *"The others' step counts were too high up…If they were more in my range, it would have been different, easier to get into the vibe of the competition." (Competition group, female)*

There were mixed observations among participants from non-competitive groups (Control group and Cooperation group). Whereas some participants were interested in experiencing a competitive element, there were concerns from other participants who felt that the competitiveness element would have added unwanted pressure and stress on them.

> *"Probably I would have been more motivated had I been playing for my team. I would have played for the team more … "(Competition group, female)*

> *"I wanted to be part of a competition. It would have made me more competitive than competing with myself" (Control group, female)*

> *"…some competitiveness would have motivated me more…" (Cooperation group female)*

> *"If I knew there was a competition involved, I would have tried to do more steps not just monitor" (Control group, male)*

> *"Life is already very competitive, we already have a lot of deadlines… it's added pressure" (Hybrid group, female)*

"In a competition you are trying to achieve, and we can't always achieve, it might not be sustainable long term, it might help to a certain limit…you might be able to do it and you might not, because you have time constraints, and other limitations, so the competition would put pressure on you." (Control group, female)

4.4.2.6 Cooperative element

The study included two gamified experiences that had an element of cooperation: i) a group challenge (Cooperation group); ii) an inter-team competition which involved participants cooperating with members of their own team, whilst competing against other teams (Hybrid group).

Participants from the group challenge remarked that the *"idea of a challenge was really cool with the pirate moving around to get the treasure" (Cooperation group, male).* Individuals reacted positively when they accomplished a challenge while cooperating as a team. A disadvantage that was clearly evident with the cooperative design is the issue of free riders and the tendency of social loafing. Not all team members were equally motivated and engaged, and this created frustration and discontent amongst those who were keen and committed to achieve the shared target.

"Disappointed … I'm a keen player, why other participants did not have the commitment to achieve the shared goal? There was a shared target and the fact that not everybody was doing the effort was demotivating and frustrating." (Cooperation group, female)

"I was upset that I didn't see the same amount of steps and effort from the rest of the team" (Cooperation group, male)

Participants from both the Cooperation Group and the Hybrid Group suggested that for team cooperation to work well, there needs to be more group cohesion. Participants felt that anonymity and the lack of social connections with other group members weakened the group cohesion.

4.4.2.7 Gratifying reward

Participants seek experiences that are meaningful. There could be a multitude of game elements, however the ones that are mostly valued are those that provide recognition for the participants' efforts, progression, and achievements. Rewards could come in many forms, either tangible or intangible. For some participants achieving the daily target and feeling the buzzing sensation of the smartwatch (as immediate feedback) upon reaching

the target was considered as a rewarding experience that contributed to feelings of satisfaction. Receiving immediate feedback about a target achieved was more rewarding than receiving points or seeing the progression status bar on the gamified application. The latter game elements were not deemed to be useful for most participants.

Achieving badges and improving their ranking on the leaderboard were the most rewarding affordances mentioned by participants. Badges were awarded to participants in the gamified groups based on their individual performance in terms of the daily step count. Receiving a badge was linked to childhood rewards, fun, happiness, and satisfaction. One participant described badges as *"a personal achievement… like a collection based on your performance" (Competition group, female).* The positive motivational effect of badges was mostly evident amongst individuals who consider themselves competitive. Badges fostered a sense of accomplishment and were considered as short-term intangible rewards.

> *"Badges took me back to my childhood like getting a lollipop…a reward that makes your day" (Cooperation group, female)*
>
> *"I was so happy when I got 20K … it was a good reward" (Competition group, female)*
>
> *"I liked it when I got a badge, until I got the 20K which was the last badge we could get. If the badges kept going higher, it would have motivated me to keep going" (Hybrid group, female)*
>
> *"The first ones [badges] were easy, the last two 18K and 20K it's like I had to do the extra push to get them… to get the 20K badge I walked for that badge as my own personal target" (Competition group, female)*

Nonetheless, badges did not influence all participants. Some participants from the gamified groups remarked that receiving a tangible reward would have increased their drive to try harder in the competitive or cooperative challenges.

> *"If you had offered a tangible reward at the end, e.g. pizza, that would have brought the competitive nature out of me, not badges" (Hybrid group, female)*
>
> *"Does this translate into me getting something like a chocolate or gift voucher?" (Cooperation group, male)*
>
> *"I believe a human being in nature does something to achieve an award." (Cooperation group, male)*

Other suggestions from participants for meaningful intangible rewards included achieving elite status based on the users' performance or unlocking exclusive features on the gamified application. For instance, one participant from the shared group challenge articulated:

"Technically nothing really happened… Like you get the treasure, but as a reward beyond badges and treasure, there is nothing new to aspire for, a better reward, not necessarily tangible…you could earn the elite status or special recognition. Recognition could be virtual…. E.g. usage of app would give you exclusivity, unique status, or open up other elements/features of the app." (Cooperation group, male)

4.4.2.8 Enticing new experiences

Participants remarked that the novelty of the experience captivates the participants' interest to make use of motivational design technologies. Several participants indicated that they were eager in the beginning out of curiosity, however their interest faded off after some time. Participants suggested the introduction of new elements, such as a new competition, challenge, or something to aspire for to sustain their engagement for a longer period.

"For the first week, it was really good, we were teasing each other, 'come on walk a bit', but after a week it kind of died out…" (Hybrid group, female)

"I was excited in the beginning, then it went down...when the competition started, it went up again… like the fun started again for me. The first 2 weeks I really liked it and I tried my best… then the last week was the lowest of excitement, because you're doing it for a month… so it was not that exciting". Hybrid group, female)

"…engaged me for the first week, out of curiosity to see what was going to happen... Just for the first time until I experienced it" (Cooperation group, male)

While new experiences are appealing, participants acknowledged that while other competitions and challenges may seem desirable, in reality these will only be engaging for a short period of time until they go through the experience.

4.4.3 Theme 3: The value of social engagement and group cohesion

The third key theme relates to the perceived value and importance of social engagement and group cohesion. The findings reveal that social engagement and group cohesion can be facilitated through disclosing participants' identity, providing opportunities for social interaction, social connections and relatedness. Participants in all of the different groups expressed similar claims towards social engagement and group cohesion. Three sub-themes emerged within this theme, and these are discussed in relation to the participants' experiences from the different groups collectively.

4.4.3.1 Identifiability

The anonymity of participants during this study weakened the potential of social engagement, social interaction, and limited the group cohesion. During the discussions, participants revealed that they were willing to disclose their names and include a profile picture on the gamified application. Several participants (from all groups) indicated that disclosing the individuals' identities encourages more commitment and motivation towards the exercise.

> *"If we put our names rather than identities disclosed, you would make a bit more effort, I think that would have more impact" (Cooperation group, male)*

> *"Something like this would be fun if it were not anonymous, if the people you know them well or there's a bond between each other." (Cooperation group, male)*

4.4.3.2 Social connections

Although participants give priority to their own personal goals, they still seek to connect with others, especially with whom they have an established social bond. Participants from all groups indicated that a team experience can be more motivating and engaging, but a sense of connectedness and cohesion among the team members is necessary for the team element to work. Participants from the self-monitoring group were keen to relate and connect with others. Some participants compared progress with their spouse, partner, colleagues, and friends. Similarly, most participants from the gamified groups indicated the experience would be more engaging and motivating if done with people they know, such as friends, family members or colleagues at the workplace. A social connection between the team members strengthens both competitive and collaborative experiences.

> *"If they were people I knew, I would tease them… the interaction and attitude would have been different, I feel more competitive with friends or people I know. (Cooperation group, male)*

> *"I think if you have a social connection it [the experience] can affect you much better and much stronger." (Competition group, male)*

> *"I didn't know people in my group, but if it would be a group with my friends, for one common goal, the chance is higher that you all work together." (Hybrid group, female)*

> *"If I knew the others, it would have influenced me more cause I'm a bad loser." (Competition group, male)*

4.4.3.3 Opportunities for social interaction

The gamified experiences provided limited opportunities for physical social interaction. Opportunities for social interaction were virtual through the application. Participants met other group members only at the initial briefing session and the post-experiment follow-up discussion session. However, several participants expressed their eagerness to meet up with other group members (for a chat or a drink, or a session at a gym) during both focus group discussions and interviews. Opportunities for social interaction help to get to know others, enhance the sense of connectedness, and facilitate group cohesion. One participant (who happened to be an avid Pokémon Go player) indicated that *"it is the social interaction that keeps it going" (Competition group, female).*

> *"... all this virtual it will become dehumanised; we had a month we meet and then maybe we start again." (Cooperation group, female)*
>
> *"We should have met at least twice during this month so that we get to know each other to have that group cohesion" (Cooperation group, male)*
>
> *"The communication [on the app] was public to all, so if I wanted to share a message to my team to try to aim for 10K steps to be higher than other groups, [private team chat] that was not possible I was interested in getting to know my team members in our group, it would have been fun rather than alone" (Hybrid group, male)*

Whereas social interaction was described as a positive aspect to enhance social support and commitment towards the group, the perceived obligations towards the group performance and pressure from friends were perceived as negative aspects.

5 Discussion

5.1 Introduction

The thesis aimed to extend our knowledge and understanding of gamification in the context of physical activity to facilitate the desired psychological and behavioural outcomes, enrich the users' experience, and support the users' overall value creation.

To this end, this thesis focused specifically on the psychological and behavioural outcomes evoked using different design choices of gamification (Section 5.2.1); the resulting effect of the emotional, cognitive and behavioural manifestations on the individuals' subjective well-being (Section 5.2.2); and the underlying processes and conditions of gamified self-tracking experiences that foster an engaging meaningful user experience to facilitate a behavioural change in physical activity (Section 5.2.3).

The discussion that follows relates to the findings and implications for each research question. The findings are discussed in relation to existing literature, drawing a comparison with respect to the similarities and differences between the findings emerging from this thesis and those from earlier empirical works. The strengths and limitations of each study are discussed, together with the implications for future research and practice. Each section concludes by summarising the main findings emerging with respect to each specific research question.

5.2 Addressing the research questions

5.2.1 RQ1: How does gamification of physical activity affect psychological and behavioural outcomes?

By conducting a purposely designed randomised controlled field experiment, this thesis provided empirical evidence that gamification improves physical activity behavioural outcomes. Compared to a non-gamified self-tracking experience of physical activity, a gamified experience resulted in statistically higher levels of physical activity (Hedge's g = 0.25). The positive effect is considered to be a small effect (Ellis, 2010; Hedges & Olkin, 1985; Lenhard & Lenhard, 2016) supporting the findings of a recent meta-analysis

synthesising existing empirical evidence in this domain (Mazéas et al., 2022). While a progressive decay trend in the mean daily step count is evident in both the gamified groups and the control group, the relative advantage of the gamified groups in comparison to the control group is sustained throughout the intervention period. This finding provides further evidence that there is potential to leverage gamification to increase physical activity.

The findings show that the hybrid gamification design which involved an inter-team competition was the most effective gamification design at increasing physical activity (Hedge's g = 0.39). The pure competitive and cooperative gamification designs resulted in smaller positive effects (Hedge's g = 0.23). This observation suggests that a combination of competitive and collaborative features resulting in a type of a hybrid design is more effective than including only cooperative or competitive gamification features. This result is consistent with earlier studies like Tauer & Harackiewicz (2004) where the combination of cooperation and competition in sports led to greater benefits, and Morschheuser et al. (2019) who looked at the effects of gamification in the crowdsourcing domain. However, the result of this thesis is in contrast to previous empirical evidence investigating gamification of physical activity (Chen & Pu, 2014), which found that a cooperative design facilitated higher physical activity than a hybrid design.

Comparing the study design, procedures and setting with previous studies may shed light on the differences in the findings, as well as provide valuable insights for future intervention studies. This study was conducted amongst people with no pre-existing social connections. Moreover, participants were assigned a unique code to ensure anonymity. Previous randomised controlled trials (Patel et al., 2019) involving participants who had no pre-existing social connections found that competition was the most effective strategy compared to social support and cooperation (the hybrid design was not included in this trial). On the other hand, the study conducted by Chen & Pu (2014) reporting that a cooperative design was more effective than a hybrid design was implemented amongst dyads of close friends. This observation suggests that cooperative designs may be more effective when individuals have close social connections, while

competitive designs seem to be more effective when participants do not have pre-existing social connections or in anonymised settings.

Considering the level of physical activity of participants in this study, all the groups in this study had a baseline step count in the range of 7,600 to 9,000 steps per day which is classified as a 'somewhat active lifestyle' (Tudor-Locke & Bassett, 2004). In a previous study conducted by Patel et al. (2019), the greatest increase in step counts was recorded amongst participants with low baseline step counts that had less than 7,500 steps per day. Similarly, positive effects of gamification reported by Gremaud et al. (2018) involved sedentary office workers. This suggests that the effect of gamification on physical activity could be higher amongst participants who have a predominantly sedentary lifestyle.

In addition to the behavioural outcome of gamification, this study examined psychological outcomes in terms of the users' intrinsic motivation (an emotional dimension) and perceived usefulness (a cognitive dimension). The findings from this thesis show that at the end of the intervention (after four weeks) gamification did not evoke stronger psychological responses relative to a non-gamified self-tracking experience. Literature suggests that enjoyment and perceived usefulness of gamification declines with use (Koivisto & Hamari, 2014). Thus, future work could consider more frequent measurements during the intervention period. Despite the lack of psychological effects, the use of gamification did result in stronger behavioural outcomes. The results suggest that gamification can act as a stimulus or a nudge that begets desired behavioural outcomes (in this case an increase in physical activity), without stimulating different psychological responses (relative to non-gamified self-monitoring interventions).

This randomised controlled field experimental study extends existing literature on the effect of gamification in the domain of physical activity - an area of research where rigorous empirical evidence is limited (Koivisto & Hamari, 2019a; Mazéas et al., 2022). In view of the lack of knowledge on which gamification elements or designs produce positive effects (Koivisto & Hamari, 2019a; Mazéas et al., 2022), this field experiment opted for a four-arm randomised controlled design to test the effect of different gamification designs. Furthermore, while the majority of existing studies focus on

behavioural outcomes, this study investigated both psychological and behavioural outcome measures resulting from gamification of physical activity.

Two key limitations to this study could be addressed in future studies. First, the small sample size limited the potential of further sub-groups to test specific game elements and further mechanisms. Finding significant effects despite the sample size strengthens the evidence that gamification could motivate behaviour change in physical activity. Some ideas that could be tested in future studies include the possibility of introducing new game elements during the intervention, offering tangible rewards rather than virtual rewards when targets are achieved, having participants' identities disclosed (provided that ethical issues are complied with) and giving more opportunities for social interaction amongst participants. Second, although this study includes a randomised controlled field experiment over a period of four weeks, it is still considered as a relatively short timeframe and longer interventions are encouraged in future studies. Understandably, there are challenges to conduct randomised controlled trials using wearable devices (to gather objective data) with large sample sizes and longer timeframes. However, the accumulation of knowledge from rigorous empirical studies on the effect of gamified interventions on health-related behaviours would have practical relevance.

To conclude, results from this randomised controlled field experiment show that gamification has the potential to induce a positive behavioural change in terms of step counts especially with the implementation of a hybrid (competitive-cooperative) gamified design. While the use of gamification stimulated the desired behavioural change, the psychological responses to gamification (albeit positive) were not significantly different to a non-gamified self-tracking experience at the end of the intervention period. The finding that gamification can stimulate a stronger behavioural outcome but does not evoke a stronger psychological one merits further investigation. Future work could investigate further the link between psychological outcomes and behavioural outcomes and explore how gamification mechanisms work.

5.2.2 RQ2: Do experiences of gamification and self-tracking of physical activity create positive emotional, cognitive, and behavioural responses that yield enhanced well-being?

The findings from this thesis support the theoretical prediction that experiences of self-tracking, alone and in conjunction with gamification yield enhanced well-being. The gains in well-being measures were attributed to the users' psychological responses, rather than the behavioural change in physical activity. Specifically, the users' enjoyment and interest were linked to the increase in the users' happiness levels. In turn, the users' perceived usefulness of the experience was associated with the increase in the users' life satisfaction levels. Our findings support existing literature suggesting that intrinsic motivation and autonomous forms of extrinsic motivation enhance well-being (Ryan & Deci, 2000b).

Both gamified and non-gamified self-tracking facilitated similar positive psychological responses at the end of the intervention, measured in terms of enjoyment and interest (hedonic benefit) and as perceived usefulness (utilitarian benefit). The findings from this thesis corroborates previous empirical evidence (Hassan et al., 2019, 2020), where self-tracking and gamification facilitated hedonic and utilitarian benefits. Experiences that provide informational feedback that is perceived to be useful, and enjoyment (affective response) have a positive effect on the consumers' intention to continue using such motivational technologies (Hassan et al., 2019; Köse et al., 2019; Stragier et al., 2016).

This study offers an insight into the positive impact on well-being which contrasts extant empirical evidence in gamification literature (Maher et al., 2015; Paul et al., 2016). Previous empirical studies (Maher et al., 2015; Paul et al., 2016) indicated that physical activity interventions involving activity trackers and gamification did not produce a significant change in well-being and quality of life measures. By contrast, the findings from this thesis suggest that experiences of self-tracking and gamification have significant positive effects on happiness (effect size r = -0.182) and life satisfaction (effect size r = -0.230). These effects corroborate the standardized effect sizes observed in previous literature following the use of self-tracking technologies (Stiglbauer et al., 2019; Vallance et al., 2007). The comparison to existing empirical literature is limited due to

the fact that few experimental studies investigating gamification of physical activity took into consideration potential well-being outcomes.

Furthermore, this thesis also offers an insight into the correlates of life satisfaction and happiness amongst the study participants. Literature suggests a positive association between physical activity behaviour and well-being (Iwon et al., 2021; Penedo & Dahn, 2005; Wiese et al., 2018). Indeed, pre-intervention data confirms that regular physical activity was one of the determinants of the individuals' life satisfaction. However, the behavioural change in physical activity was not linked to the increase in well-being.

The findings from this thesis corroborate previous literature (Medvedev & Landhuis, 2018) showing a high positive correlation between happiness and life satisfaction. Similar to previous literature (Briguglio, 2019; Selim, 2008), participation in religious or spiritual activity, socialisation with family and friends, regular physical activity, spending time in nature and having a balance between work and play were factors that positively influence well-being. By contrast, being in a steady relationship, having sufficient income, participation in voluntary work and creative activities were not found to be significant predictors of life satisfaction and happiness. Also, the results from this thesis indicate that being in full time employment negatively influences well-being. While employment typically has a positive influence on well-being (Briguglio, 2019), this is generally in comparison to unemployment. The contrasting results found in this thesis may be due to the fact that all participants in this study were either employed part-time or full-time, or engaged in post-graduate studies, and thus it does not capture data from other segments of the general population.

The findings from this study provide insights into how subjective well-being is influenced by self-tracking technologies and the use of gamification, an area which is underexplored in literature. Yet, despite the contributions, there are two limitations which could be addressed in future research related to this study. First, this study examined well-being measures pre- and post-intervention. Future studies could consider gathering data on psychological outcomes and well-being measures more frequently during the intervention to examine whether the users' psychological responses and the effect on well-being varies during the intervention. Also, future work with longer timeframes could explore long-

term health and well-being impacts. Second, this study compared longitudinal well-being data of gamified and non-gamified self-tracking experiences. Future studies could also include a control group, with no access to physical activity trackers.

To conclude, results from this longitudinal study demonstrate that there is potential to enhance well-being through the intrinsically motivating experience and perceived usefulness of self-tracking technologies and gamification. The value co-created through such meaningful experiences improves people's quality of life and well-being.

5.2.3 RQ3: How do gamified self-tracking experiences foster motivation towards physical activity?

The findings from this thesis contribute to a better understanding of how self-tracking and gamification can provide engaging experiences that foster motivation towards physical activity and enhance the users' value creation. First, this qualitative study contributes to literature by identifying the elements that nurtured motivation towards physical activity, and those that to a certain extent thwarted the desired response. Second, the insights gained from the participants' subjective experiences shed light on *how* and *why* these motivational affordances foster or hinder the individuals' motivation towards physical activity. The findings suggest that the underlying emotions, feelings, and cognitive processes elicited by these motivational affordances are compatible with the core constructs of the self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2000b). Specifically, the findings indicate that gamified self-tracking experiences have the potential to enhance motivation by providing a gratifying experience that supports empowerment, autonomy, competence, progress, achievement, and social relatedness.

The key factors that fostered motivation towards physical activity include personal goal setting, immediate and regular feedback, social comparison, competitive and cooperative elements, a sense of community spirit, gratifying rewards, and enticing new experiences. Conversely, anonymity made it harder for participants to interact with others, limited the group cohesion and the potential for social engagement. Leveraging pre-existing social connections and providing opportunities for social interaction facilitates group cohesion. The findings from this thesis highlight the value of social engagement and group

cohesion. The forthcoming paragraphs connect the findings to literature and outline how specific elements related to self-tracking and gamification support the individuals' innate psychological needs that nurture the users' motivation towards physical activity.

Self-knowledge garnered from the use of physical activity trackers enabled users to reflect and be able to take decisions intended to improve their physical health and well-being. This thesis extends existing literature (Feng et al., 2021; Li et al., 2010; Stiglbauer et al., 2019) suggesting that people use self-tracking technologies to optimise their health and general well-being. A *sense of empowerment and control* was provided through the acquisition of self-knowledge, corroborating the findings from Pingo and Narayan (2020). The experience of self-tracking physical activity and other health-related behaviours was perceived to be useful, and several participants expressed their intention for continued usage of self-tracking technologies. This finding is consistent with previous empirical evidence (Chuah, 2019; Hassan et al., 2019; Shin & Biocca, 2017) which suggests that the perceived benefits provided by self-tracking technology are associated with continued use intentions.

Goal setting emerged as a prominent positive influence on physical activity. Consistent with literature (Latham & Locke, 1991), setting clear, specific and realistic goals is conducive to better performance. Corroborating the findings from prior studies (Kappen et al., 2018; Kappen et al., 2020), goal setting was one of the key elements that facilitated motivation to participate in physical activity. Achieving the target step goals supported the individuals' motivation, through *feelings of accomplishment*, *competence and satisfaction.* Similar to the findings from Corepal et al. (2018), most participants engaged in self-competition, aiming to increase their physical activity to achieve a higher step goal than those achieved on previous days. The freedom of setting personal goals provided a *sense of autonomy* and mitigated the potential adverse effects of external regulation which could negatively affect users' intrinsic motivation (Ryan & Deci, 2000b).

Receiving immediate and positive feedback about their performance provided recognition to the participants' efforts and contributed to *feelings of satisfaction*. This observation is consistent with the findings in previous studies (Corepal et al., 2018; Kappen et al., 2017, 2020; Peng et al., 2016). Echoing previous literature (Li et al., 2010;

Rapp et al., 2018), wearable physical activity trackers and the corresponding mobile application in this study provided users with immediate informative feedback on their performance, enabling self-reflection and stimulating behaviour change. The vibration alerts provided by the wearable physical activity trackers on the users' wrists upon reaching the daily step goal was perceived as informative feedback that *reinforced feelings of achievement, competence and satisfaction*. Informative information that is perceived useful for the users *supports the need for competence* and enhances motivation (Deci & Ryan, 1985). The findings indicate that informative feedback on their progress and achievements was gratifying and appreciated more than points and progress bars. In accordance with previous literature (Rapp, 2015), integrating common game elements such as points do not necessarily improve the user experience. Designing a gamified system does not guarantee value creation.

The presence of social features is widespread in gamified applications of physical activity (Neupane et al., 2020), and literature shows that interpersonal social contexts are conducive to better performance compared to individualistic contexts (Stanne et al., 1999). Indeed, a **group setting** was the preferred choice compared to an individual setting among participants in this study. Participants were keen to interact with others, compare progress and make social connections. In this thesis, participants who had an individual self-tracking experience also expressed their interest to share and compare their performance with others. The **sense of community spirit** amongst the group members emerged as a determining factor that fosters motivation amongst the team players. Nonetheless, it is evident that even though a group setting promotes higher engagement and motivation, personal goals are prioritised over team goals.

Social comparison features had a prominent influence on physical activity behaviour. Participants in the gamified groups indicated that social comparison made the experience more engaging and provoked competitiveness to achieve higher step counts. Specifically, leaderboard rankings promoted social comparison and supported *a sense of progression and achievement*. The evidence from this thesis is consistent with the findings of previous studies (Chen & Pu, 2014; Corepal et al., 2018; Edney et al., 2020; Peng et al., 2016) where social comparison motivated participants to achieve higher individual performance. However, large discrepancies between the participants' performance makes

the competitive aspect less appealing, because they feel that others' performance is not within their league. This finding is also reflected in previous literature (Chen & Pu, 2014; Lin et al., 2006; Rapp, 2015). Nonetheless, most participants were still aiming for progress by focusing on outperforming the participants ahead of them on the leaderboard ranking. Future gamified interventions should consider grouping participants according to their level of performance where people within the same group share similar levels of performance.

This study extends the findings of previous research (Lin et al., 2006; Rapp, 2015) regarding **competitive and cooperative gamification designs**. This study finds that both positive and negative reactions were reported for the three different gamification designs, namely: i) competitive; ii) cooperative and iii) hybrid (competitive-cooperative). Each gamified design offered a stimulating experience for some participants, but not for everyone. Participants' preferences can change over time and are influenced by multiple factors including the individuals' personality, social connections with others, and the individuals' current situation. Providing a variety of competitive and collaborative experiences and allowing individuals to engage with the gamified system in different ways fosters *a sense of autonomy* and maximises the possibility of enhancing value creation.

Earlier studies found that while competitiveness is stimulating for some individuals, others find it unnecessary (Lin et al., 2006; Rapp, 2015). Indeed, the findings from this study report similar observations. In view of the individuals' differences, supporting competition with cooperative activities could help in offering an engaging experience to different individuals (Rapp, 2015). However, this thesis observed that cooperative experiences risk harming the intrinsic motivation of those who are truly engaged in a group collaborative effort. In this study, participants expressed a sense of frustration and discontentment when others did not show the same level of commitment in collaborative activities. While gamification could be employed as an engagement marketing technique to enrich the user experience and support behavioural change, the possibility of harming intrinsic motivation and/or creating psychological distress needs to be examined further in future research. Potential ethical considerations including psychological distress and

unintended behaviours such as cheating need to be addressed when employing the use of gamification (Al-Msallam et al., 2023).

New experiences were enticing, but only for a short-term. The presence of novelty effects with gamified activities was evident in this study. Over time, engagement with the gamified application declines due to being perceived as repetitive (Corepal et al., 2018; Lin et al., 2006; Rapp, 2015). Literature suggests that the users' interest, perceived enjoyment and usefulness of gamification declines over time (Koivisto & Hamari, 2014). To be continuously captivating and intriguing, new elements could be introduced along the way. Trying a different type of challenge or competition to rekindle the individuals' interest and engagement was suggested by participants. Despite the fact that the 'grass may seem greener on the other side', the users' qualitative feedback indicates that new extrinsic motivational affordances are only effective in the short-term until the user gets a first-hand experience of the new activity.

Self-tracking and gamified experiences provided **gratifying and rewarding experiences**. For instance, informational feedback (including the vibration alerts from the smartwatch) was perceived as a rewarding experience that provided reinforcement for the desired behaviour. Receiving badges linked to achieving higher step counts and seeing progress on the leaderboard ranking were also linked to rewarding feelings. Other potential meaningful rewards suggested by participants include achieving an elite status or unlocking exclusive features based on the users' performance and tangible rewards such as gift vouchers. This thesis finds that experiences that are meaningful and relevant for the users are essential to sustain interest and engagement over the longer term.

The insights gained from the users' subjective experiences highlight the importance and value of ***social engagement*** with others. Users reported that *a sense of social connectedness* fosters higher motivation compared to an individual self-tracking experience. The *sense of relatedness* is especially important for internalisation of extrinsically motivated behaviours (Ryan & Deci, 2000b). Literature indicates that sharing activity data and progress with others positively influences hedonic motivation (Ryan & Deci, 2000b; Suh, 2018). Participants indicated they would prefer to share the activity data with people they know, such as family members, friends, and colleagues.

The findings suggest that leveraging existing social bonds facilitates enhanced intrinsic motivation to participate in competitive and cooperative gamified activities. Similar findings are also reported in online multi-player video games (Rapp, 2017). A social environment that supports the basic psychological need of relatedness is more likely to foster motivation and behaviour change (Ryan & Deci, 2000; Moore et al., 2011; Podlog & Dionigi, 2009).

In this study, *social engagement* was hindered by the fact that participants' identities were kept anonymous. Disclosing participants' identities helps users to establish social connections. During follow-up discussions, participants did not express any concerns in disclosing their identity and their step count data with others. Future research examining the effect of gamification on physical activity should consider non-anonymity of participants. Participants reported that the interventions provided limited opportunities for social interaction. Indeed, participants expressed the desire to meet up and engage with others physically, rather than solely through virtual means. The findings suggest that providing opportunities for social interaction facilitates the development of a social network which provides social support. Closeness amongst team members enhances the level of users' engagement and motivation in social settings. Consistent with previous studies (Corepal et al., 2018; Kappen et al., 2020; Kerkelä et al., 2015), social support encourages participation in physical activity behaviour. Furthermore, consistent with the self-determination theory, motivation is more likely to thrive in contexts characterised by a sense of relatedness and social support (Ryan & Deci, 2000b).

In synthesis, the qualitative findings provide evidence that gamification in conjunction with self-tracking can be leveraged to foster motivation towards physical activity and support the users' value creation by providing a gratifying experience that supports empowerment, autonomy, competence, progress, achievement, and social relatedness.

5.3 Conclusion

This chapter summarised the findings for each research question and discussed the implications of these findings. The outcomes from this thesis as well as the approach adopted for this research have been compared with those of previous empirical studies in

this domain. Strengths and limitations specific to each research strategy that could provide insights for further research avenues were discussed in this chapter. Next, the concluding chapter presents the theoretical and practical contributions, followed by the limitations of this thesis and the implications for future research.

6 Conclusion

This thesis set out to explore the potential of employing gamification as a marketing strategy to promote positive experiential and behavioural outcomes that support the users' value creation. Indeed, this thesis investigates how and to what extent gamification can be utilised to create engaging and meaningful experiences that facilitate positive psychological outcomes and behavioural change in physical activity. Specifically, this thesis examined i) how the choice of gamification design affects the users' psychological and behavioural responses; ii) the resulting effects of the emotional, cognitive and behavioural manifestations on the individuals' subjective well-being; and iii) the factors and underlying processes of gamified self-tracking experiences that foster an engaging meaningful user experience.

These objectives are consistent with a critical realist philosophical stance, involving a mixed-methods research approach manifest through three different research strategies. First, a purposely designed randomised controlled field experiment examined how the choice of competitive, cooperative and hybrid (competitive-cooperative) gamification designs affect outcomes. This experiment generated a panel dataset of step counts (objective data) that helped examine the behavioural change led by gamification. Furthermore, self-reported data was gathered on the users' emotional and cognitive psychological responses. Second, a longitudinal survey study helped examine how subjective well-being is influenced by experiences of self-tracking and gamification of physical activity. Third, a qualitative study sought to gain deeper insights into the gamification mechanisms and the underlying psychological processes that fostered motivation towards physical activity behaviour.

The insight emerging from this thesis offers theoretical and practical contributions (discussed in Sections 6.1 and 6.2 respectively) that complement each other and shed light on how gamification can be utilised to create engaging and meaningful experiences that facilitate the desired psychological and behavioural outcomes to support the users' overall value creation. Section 6.3 elaborates on the insights gained through this thesis for marketing strategy in the pursuit of value creation through gamification. Section 6.4

discusses the general limitations and directions for future research and Section 6.5 presents the concluding remarks.

6.1 Theoretical contributions

There are three key theoretical contributions emerging from this thesis.

First, the thesis investigated the psychological effects and behavioural change resulting from gamification of physical activity (RQ1). In view of the need for rigorous experimental studies to isolate and estimate the effects of gamification (Johnson et al., 2016; Koivisto & Hamari, 2019a), a randomised controlled field experiment was conducted. Literature suggests various ways how gamified systems could be designed (Liu et al., 2013; Morschheuser et al., 2017), but there is limited evidence on which type of design is most optimal in the context of physical activity. Based on established classification frameworks of gamification design (Liu et al., 2013; Morschheuser et al., 2017), this study compared three socially oriented types of gamification interventions, namely i) competitive, ii) cooperative, and iii) hybrid (combination of competitive-cooperative elements).

Objective measures were utilised to ascertain whether gamification led to a behavioural change. Relative to a non-gamified self-tracking experience, it has been shown that all groups treated with gamification recorded an increase in physical activity behaviour during the intervention period. This finding adds to current empirical evidence (Koivisto & Hamari, 2019a; Mazéas et al., 2022) substantiating the positive effects reported from gamification on physical activity behaviour. While literature has mainly focused on whether gamification works (Nacke & Deterding, 2017), this study extends the contribution to literature by providing insight into which gamification design facilitated the strongest behavioural change. The results revealed that a hybrid gamification design using an inter-team competition facilitated the highest increase in physical activity behaviour. The similarities and differences between the current study and previous empirical works were presented in Section 5.2.1.

Moreover, this thesis provides evidence on the psychological effects resulting from gamification of physical activity. Previous experimental research examining the effect of

gamification on physical activity behaviour have largely neglected the users' psychological responses to gamified interventions (Mazéas et al., 2022). Surprisingly, the findings in this thesis revealed that while the use of gamification stimulated the desired behavioural change in physical activity, it did not stimulate stronger psychological outcomes when compared with non-gamified self-tracking at the end of the intervention period. This contribution is theoretically interesting and merits further research into the mechanisms at play. The outcome from this study prompts re-thinking of extant gamification literature (Hamari et al., 2014; Huotari & Hamari, 2017), which suggests that gamification features are implemented as motivational affordances that stimulate psychological outcomes, which in turn lead to the behavioural outcomes. Future research needs to explore and understand how gamification nudges the desired behavioural outcome, without stimulating different psychological responses from non-gamified experiences.

Second, this thesis investigated how subjective well-being is influenced by self-tracking and gamification of physical activity (RQ2). Literature suggests that gamification and self-tracking can have positive effects on well-being, however empirical evidence is limited and inconclusive (Johnson et al., 2016; Schmidt-Kraepelin et al., 2020; Stiglbauer et al., 2019). To this end, this thesis measured happiness and life satisfaction as two indicators of subjective well-being, before and after gamified and non-gamified self-tracking experiences of physical activity. Results supported the theoretical prediction that experiences of self-tracking, alone and in conjunction with gamification enhance well-being. At the end of the four-week intervention period, gamified and non-gamified self-tracking yielded similar positive psychological responses and similar well-being gains.

This thesis extends existing literature by quantitatively examining whether the increase in well-being is linked to the psychological responses and/or the behavioural change resulting from self-tracking and gamification. The results revealed that the increase in well-being was attributed to the positive psychological responses resulting from these experiences, rather than the behavioural change in physical activity. Specifically, the users' enjoyment and interest were linked to an increase in the individuals' happiness levels. These findings extend existing literature indicating that both gamification and self-tracking facilitate affective and enjoyable experiences (Hassan et al., 2019), providing

emotional value to the user. By contrast, the perceived usefulness of these experiences was associated with an increase in the individuals' life satisfaction. The perceived usefulness of these experiences facilitates internalisation and integration of extrinsically motivated behaviours (Ryan & Deci, 2000b). The advantages of internalisation include more autonomous and volitional commitment towards the desired behaviour and enhanced subjective well-being (Ryan & Deci, 2000b). In synthesis, the results suggests that the hedonic benefit of the experience enhances happiness levels (hedonic well-being), while the utilitarian benefit of the experience enhances life satisfaction levels (eudaimonic well-being).

Third, this thesis contributes to literature by exploring the mechanisms and the underlying psychological processes through which gamification combined with the use of wearable physical activity trackers motivated users and inspired the desired behavioural change (RQ3). In view of the need for mixed-methods research to provide a comprehensive evaluation on the effects of behavioural interventions of physical activity (Aldenaini, Alqahtani, et al., 2020; Seaborn & Fels, 2015), a qualitative study was conducted to uncover insights that are not measured through quantitative measures. This study was conducted following the field experiment (conducted to answer RQ1) involving different gamified interventions (including competitive, cooperative, hybrid designs) and a non-gamified self-tracking experience. Focus group discussions and one-to-one interviews explored which elements from these experiences nurtured or hindered motivation towards physical activity. Motivational factors included personal goal setting, feedback, social comparison, a sense of community spirit, competitive and cooperative elements, gratifying rewards and enticing new experiences. By contrast, anonymity, lack of social interaction and weak group cohesion were perceived as limiting factors.

To foster motivation and support value creation through gamification, it is essential to understand *how* and *why* specific elements related to gamification and self-tracking technologies influence the users' motivational psychology (Koivisto & Hamari, 2019b; Nacke & Deterding, 2017). The rich insights gathered through this qualitative study revealed that specific elements related to gamification and self-tracking evoked autonomous motivation by supporting the individuals' innate psychological needs. The findings are theoretically interesting from the perspective of the self-determination theory

(Ryan & Deci, 2000b). The underlying psychological processes that led to the emotional, cognitive and behavioural manifestations were consistent with the core constructs of the self-determination theory, namely providing support for competence, autonomy and social relatedness (Ryan & Deci, 2000b). This observation extends earlier research (Suh et al., 2016) that proposes that gamification engages users through the mediation of psychological needs satisfaction.

The psychological need for competence is best satisfied within structured environments that provide positive feedback and opportunities for growth (Ryan & Deci, 2020). Indeed, game elements that provided feedback on the individuals' performance (such as badges and leaderboard rankings) supported the psychological need for competence and encouraged progression. In addition, feedback through wearable physical activity trackers, including sensory feedback (such as the vibration notification of the smartwatch upon achieving the daily step goal) evoked feelings of competence that fostered autonomous motivation. The findings extend the contributions from previous quantitative studies investigating how specific game elements (Sailer et al., 2017) and different types of gamification features (Xi & Hamari, 2019a) are associated with specific psychological needs.

The need for autonomy is supported by experiences that are of interest and value to the individual (Ryan & Deci, 2020). Based on the findings for RQ1, both gamified and non-gamified self-tracking experiences were considered to be useful and interesting. The qualitative study finds that autonomy was supported through gaining knowledge about users' level of physical activity, and the freedom of setting personalised step goals. Enabling the freedom to choose from a variety of competitive and collaborative gamified experiences enhances autonomy.[24] However, while individuals expressed their interest in trying new challenges or competitions, the novelty of such experiences tends to wear off after a short time (Koivisto & Hamari, 2014).

[24] Participants were not able to choose their preferred gamified self-tracking experience since they were randomly allocated to either a non-gamified self-tracking experience or one of the gamified experiences (competitive, cooperative or hybrid) to examine the effect of different gamification designs on psychological and behavioural outcomes (for RQ1).

The psychological need for social relatedness and connectedness with others is especially important for the integration of extrinsically motivated behaviours (Ryan & Deci, 2000b). Users' experiences suggested the importance of connecting with others, especially those to whom they are related or attached through existing social bonds. A social setting that provides opportunities for social comparison, social support and sharing with others was the preferred choice relative to an individual setting. Previous empirical evidence suggested that social influence had a positive impact on the individuals' attitudes and willingness to use gamified applications related to physical exercise (Hamari & Koivisto, 2015b). Leveraging pre-existing social connections and providing opportunities for social interaction enhances the social value that such experiences can provide, contributing to increased overall value created.

To conclude, the qualitative findings contributed to enhanced knowledge on how gamification can be implemented in conjunction with self-tracking technologies to create self-motivation towards physical activity. In synthesis, the qualitative findings suggest that gamification together with self-tracking technologies can foster motivation towards physical activity by providing meaningful and gratifying experiences that support the individuals' progress and achievement, a sense of autonomy and the need for relatedness.

6.2 Practical contributions

Maintaining regular physical activity is known to be beneficial for the individuals' health and well-being (WHO, 2020). Yet, despite the ongoing health promotion efforts, insufficient physical activity remains a prevailing problem (WHO, 2020). The findings from this thesis provide three key practical implications and recommendations.

First, empirical evidence from this thesis suggests that integrating gamification with wearable physical activity trackers increases physical activity behaviour. The findings from this thesis support previous literature (Hamari & Koivisto, 2015b; Tu et al., 2019) suggesting that employing social gamification features is beneficial. An optimal design was found to be a combination of competitive and cooperative game elements, resulting in a type of inter-team competition. While an element of competitiveness was found to be stimulating, supporting cooperation along with competition as suggested in previous

literature (Rapp, 2015) promises better outcomes. Thus, it is recommended to use social gamification features in conjunction with wearable physical activity trackers to stimulate a behavioural change in physical activity.

Second, the findings from this thesis highlight that gamification should be integrated in a way that provides opportunities for individuals to satisfy their innate psychological needs, including the need for competence, autonomy and relatedness (Ryan & Deci, 2000b). The use of gamification is a promising way to increase users' engagement and facilitate the desired behavioural change (Hamari et al., 2014). However, game elements should not be employed hastily (Burke, 2012; Liu et al., 2017). Practitioners should consider the principles from theoretical frameworks and the knowledge gained through empirical studies to implement gamification in a structured and planned manner to achieve optimal results.

Practitioners seeking to enhance users' motivation and engagement towards physical activity through gamification should focus on providing informative feedback on the individuals' performance, progress, and achievements. Feedback provides knowledge. It fosters a sense of competence and satisfaction by highlighting the users' achievements and milestones. Furthermore, it provides a sense of empowerment as it enables users to track their progress and allows individuals to autonomously set their personal goals. Goal setting plays an important role in motivating people to achieve better performance at the task at hand (Latham & Locke, 1991; Locke & Latham, 2002). Goals should not be imposed (such as achieving 10,000 steps a day). Rather, the design of gamified systems should encourage progress, while providing autonomy in choosing personalised goals.

The influence of others, especially those with whom individuals have an existing social bond should not be underestimated. Being part of a team or group (i.e. a social setting) drives individuals to achieve higher performance. Specifically, game elements that promote social comparison stimulate higher performance by activating the individuals' competitive spirit. The design of gamified systems should provide a variety of challenges (including both competitive and cooperative gamification features) and individuals should freely be able to choose the ones that are of interest to them.

Finally, in addition to increasing physical activity through gamification, the findings demonstrate that using wearable fitness trackers (with and without the use of gamification) increases subjective well-being. The hedonic benefits derived from using such motivational technologies enhance happiness levels, while the utilitarian benefits of using such technologies enhances life satisfaction levels. The value co-created through such meaningful experiences improves people's quality of life and well-being.

6.3 Insights for marketing strategy

Insights emerging from this thesis suggest that gamification employed as a marketing strategy can support value co-creation on three levels, namely on a behavioural level, experiential level and a social level.

First, scientific empirical evidence from this thesis shows that gamification facilitates positive behavioural outcomes. Using gamification as a stimulus begets the desired behavioural change (in this case an increase in step counts). The combination of competitive and collaborative game elements is more effective than including only competitive or cooperative gamification features. While the positive behavioural outcomes were sustained in the short-term, a progressive decline in step counts over the intervention period suggests the presence of novelty effect. Thus, positive behavioural outcomes evoked through gamification may be short-lived. Further research is necessary on the long-term behavioural effects.

Second, at an experiential level, participants' subjective experiences suggest that gamification could influence motivation and enhance the users' experiences by providing a gratifying experience. This gratifying experience supports empowerment, autonomy, competence, progress, achievement, and social relatedness. However, whereas gamification could be used within the realm of engagement marketing to enrich the users' experience, qualitative insights suggest that gamification may elicit both positive and negative emotions. Positive outcomes, such as feelings of satisfaction, achievement, progress, and enjoyment facilitated through gamification ultimately contribute to the overall value created to the user. By contrast, potential unintended negative emotions, such as frustration and discontent, psychological distress or unintended behaviours, such

as cheating and social loafing could lead to value destruction rather than value creation. Thus, a critical reflection on the unintended consequences and ethical implications is necessary when planning to employ gamification practices.

Empirical evidence from this thesis also suggests that experiences that foster intrinsic motivation and autonomous forms of extrinsic motivation enhance well-being. Specifically, enjoyment and interest (hedonic benefit) enhance the individuals' happiness levels. Similarly, perceived usefulness of the experience (utilitarian benefit) enhances the individuals' life satisfaction levels. In this study, both gamified and non-gamified self-tracking experiences led to similar positive psychological outcomes (in terms of intrinsic motivation and perceived usefulness of the experience), that in turn yielded enhanced well-being. This observation justifies further research to better understand how gamification can elicit stronger psychological responses.

Third, insights emerging from this thesis suggest that social-oriented gamification features contribute to value creation by facilitating a sense of relatedness and connectedness with others. Qualitative insights revealed that a social setting that provides opportunities for social interaction, social comparison and social engagement fosters enhanced user engagement and promotes increased motivation. User engagement is driven by the potential benefits that users expect to achieve both on a personal level and on a social level. Thus, gamification could be leveraged to contribute to value co-creation by providing an experience that affords a sense of relatedness, while promoting a sense of autonomy and competence on a personal level.

In conclusion, this thesis extends our understanding of how gamification can be effectively used to contribute to the ultimate goal in marketing, that of supporting value co-creation. Drawing on this insight, future research is encouraged to explore the overall value created through gamification on a behavioural level, experiential level and on a social level in other consumer-oriented services.

6.4 Limitations and future research

This thesis has extended our knowledge and understanding of employing gamification techniques in the context of physical activity and well-being. Nonetheless, the limitations

of this research should be acknowledged and discussed as these provide avenues that could be explored in future research. While specific limitations pertaining to the research methods were articulated in the Methodology chapter (see Section 3.9), the following paragraphs discuss four general limitations of this thesis.

First, this study was conducted amongst academic members and post-graduate students. Future studies should widen the applicability and generalisability of the results by examining the effects of gamification and self-tracking amongst other segments of the population and in different settings. For instance, although the study' participants shared a common background in academia, participants did not have a close social bond and their identities were anonymised for this study. Future studies could investigate the effect of the three gamification designs in a setting where the participants' identities are disclosed (provided that ethical issues are complied with) and/or amongst participants who are related or attached through existing social bonds. The findings from this thesis suggest that group cohesion between the team members provides a nurturing environment that could improve users' engagement and motivation towards the desirable behavioural outcomes. Consistent with the self-determination theory, motivation is more likely to thrive in contexts characterised by a sense of relatedness and social support (Ryan & Deci, 2000b). Having identities disclosed helps users to establish social connections. Moreover, providing opportunities for social interaction may facilitate group cohesion and the development of a social network which provides social support.

Second, the study considered enjoyment and interest as indicators of emotional responses reflecting the users' intrinsic motivation, and perceived usefulness as an indicator of the cognitive psychological response. It is not excluded that there may be other measures or indicators which could be assessed to examine the psychological outcomes and value elicited through gamification, such as satisfaction (Oliver & Mano, 1993) and experiential value (Chan, 2017). Moreover, previous studies have found that personal characteristics influence how individuals react to of gamification features and thus the resulting psychological and behavioural outcomes may vary based on these characteristics (Bittner & Shipper, 2014; Koivisto & Hamari, 2014; Robson et al., 2016). Thus, future research could compare differences in the psychological and behavioural outcomes observed based

on the participants' personal traits, such as personality (McCrae & John, 1992) and player types (Hamari & Tuunanen, 2014).

Third, at the time of planning the experimental study, an off-the-shelf fitness application that catered for the scope of the study with three distinct gamified experiences (competition, cooperation, hybrid) could not be identified. Thus, gamified interventions were purposely designed using a gamification platform (Pointagram). Advances in technological developments including data integration, data analytics, artificial intelligence, chatbots, and internet of things could facilitate the design of gamified systems and the data insights that could be generated. For instance, a fitness application could integrate various gamification design features that may be customised to the individuals' preferences and needs. Data generated from wearable devices could be integrated automatically with the gamified application and real-time customer insights on the user experiences and well-being indicators could be generated through in-built features of the application. Real-time customer experience tracking of the users' interactions with gamified systems would capture instantaneous feedback avoiding post-experience surveys which rely on participants' recall. Real-time tracking would allow more granular data on the users' interaction with specific gamification features and a more comprehensive view of the user experience (Baxendale et al., 2015; Macdonald et al., 2012). Data-driven predictive user-centric platforms could offer a unique opportunity to integrate such metrics and customer insights to provide personalised gamified experiences that create customer value and satisfaction.

Finally, this thesis explored the potential impact of gamification on psychological and behavioural outcomes in the context of physical activity and well-being. Possible implications of these favourable effects on society in general, such as reducing obesity and related non-communicable diseases, improving mental well-being and other related economic considerations fall outside the scope of this thesis. However, one may explore other health-related considerations, economic and social implications in future research. The accumulation of knowledge from rigorous empirical work on the effect of gamified interventions on health-related behaviours and societal well-being would have practical relevance.

6.5 Concluding remarks

This thesis sought to extend our understanding on how gamification can be utilised to create engaging and meaningful experiences that facilitate the desired psychological and behavioural outcomes to support the users' overall value creation. This study was motivated by the shortcomings in existing empirical evidence that prevent us from a comprehensive understanding of the effects of gamification in the context of physical activity and well-being.

To this end, this thesis collected and examined empirical evidence on how gamification of physical activity influenced psychological and behavioural outcomes. Empirical insights were provided on how the choice of competitive, cooperative and hybrid gamification designs affect outcomes. Results show that gamification induced a positive behavioural change in physical activity, especially with the implementation of a hybrid gamified design. While the use of gamification stimulated the desired behavioural change, the psychological responses to gamified intervention (albeit positive) were not stronger when compared to a non-gamified self-tracking group at the end of the intervention period.

This thesis provided empirical evidence that both gamified and non-gamified self-tracking experiences evoked similar positive psychological responses, yielding similar gains in well-being. The users' perceived usefulness of the experience was associated with an increase in the individuals' life satisfaction, while enjoyment and interest were linked to an increase in the individuals' happiness.

Finally, empirical insights and practical implications were also provided on how gamification could be integrated with self-tracking experiences to create engaging experiences that foster self-motivation towards physical activity. The findings suggest that gamification together with self-tracking technologies can foster motivation towards physical activity by providing a gratifying experience that supports empowerment, autonomy, competence, progress, achievement, and social relatedness.

In conclusion, gamification can be utilised to create engaging experiences that facilitate positive outcomes on a behavioural, experiential and social level, ultimately contributing to the overall value created.

7 References

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8 Appendices

8.1 Appendix A: Photos documenting the fieldwork process

Tagging process of wearables

Figure A1: Tagging of wearable physical activity trackers

Documentation for each treatment group (colour coded)

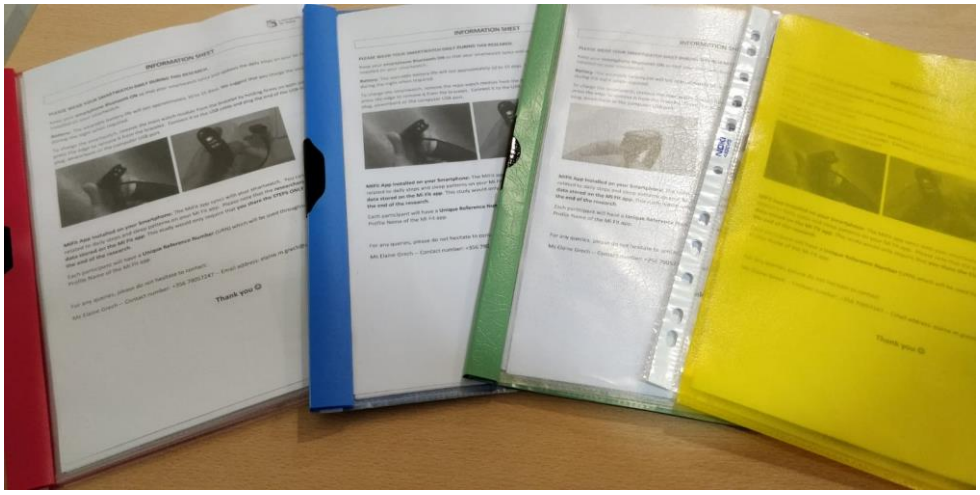

Figure A2: Information meetings documentation for each group (colour-coded)

One of the introductory briefing sessions conducted prior to the trial

Figure A3: Information sessions for participants

Room setup for one of the debriefing sessions conducted at the end of the trial

Figure A4: Room setup for the debriefing sessions

8.2 Appendix B: Participant information and consent form

Recruitment email

Target group:

ALL current post-graduate research student and academic researchers registered at University of Malta (full-time & part-time)

Title of Email:

Invitation for Research Participants to use a Smartwatch for one month

Email Content:

Dear post-graduate research student / Dear academic,

I'm Elaine Grech, PhD researcher at the University of Malta under the supervision of Dr Emanuel Said and Dr Marie Briguglio. My research focuses on the effect of using game elements to increase physical activity. Research has shown that post-graduate research students / academic researchers are under constant pressure and stress to succeed. Such reality makes it even harder for researchers to maintain a healthy lifestyle and engage in physical activity, putting their health and well-being at risk. My research focuses on understanding how different experiences of monitoring our physical activity may enhance our well-being. Your participation in this study will contribute a lot to our understanding and knowledge on how to improve physical activity and well-being amongst post-graduate research students and academics.

You are kindly being invited to participate in this research on physical activity and well-being. If you accept to take part in this research, you will be given a smartwatch for a period of 4 weeks. You will be asked to:

- Wear it to monitor your daily steps
- Connect to a smartphone app
- Share your daily steps
- Complete an online anonymous questionnaire before and after your experience, and
- You may be invited to participate in a discussion following your experience.

To check whether you are eligible to participate in this research and confirm your consent, please click: https://uom.eu.qualtrics.com/jfe/form/SV_2sjlirqBVIZwsm1 . You will then be contacted to pick up your smartwatch as from January 2020, which needs to be returned at the end of the 4-week period.

None of the information used and stored during this project will identify you. All the data will be dealt with in accordance to GDPR, and ethics forms for this research have been duly submitted as per UM UREC procedures.

Thank you.

Kind regards,

Elaine Grech

Information and Consent Form

The Impact of Quantified Self Experiences on Physical Activity &Well-Being

You are invited to participate in a research programme intended to assess and improve physical activity and well-being over a period of 4 weeks from January 2020.

If you accept to take part in this research, you will be asked to:

- Wear a smartwatch for 4 weeks to monitor your daily steps
- Use a smartphone app that connects to your smartwatch
- Share the daily steps
- Complete an online anonymous questionnaire before and after your experience, and
- You may be invited to participate in a discussion following your experience.

We will only ask for your contact details to contact you to pick up your smartwatch. The researchers will not have access to the data generated by the smartwatch except for the daily steps which you will share. None of the information used and stored during this project will identify you. No one except for the researchers will have access to the data gathered from the surveys.

It is entirely your choice whether to participate or not, you may opt out at any point and the choice that you will make will have no bearing on your work or studies at the University of Malta.

In order to participate in this study:

- You need to be over 18 years of age;
- Did not use a smartwatch or a wearable to monitor your physical activity during the last year; and
- There is no health reason (such as heart condition, chest pain, bone/joint pain, or dizziness) why you should not engage in physical activity. If you are currently pregnant or you have been told by your doctor not to engage in physical exercise, you would not be able to participate in this study.

Any questions about this research may be sent to
Ms Elaine Grech elaine.m.grech@um.edu.mt or
Dr Marie Briguglio marie.briguglio@um.edu.mt

Please tick as appropriate
I confirm that I have read and understood the information about the project and
I AGREE to participate in this study Yes ☐ No ☐

Conditionality: Send to end if NO.

Please include your contact details to contact you to pick up your smartwatch:

These details will only be used to contact you regarding the smartwatch. These details do not form part of the research data for this study. All research data gathered will be attributable to a Unique Reference Number that will not be linked to your personal data. Records of e-mail addresses and contact numbers will only be kept for the duration of this project and will be discarded following completion of the project.

Email: _____ ***Contact number:*** _____

Participant Information & Consent Form for Qualitative Study

The Impact of Gamified Self-Tracking Experiences on Physical Activity and Well-being

Following your experience of monitoring your physical activity for one month, you are kindly invited to return your smartwatch and share your insights from this experience. The idea is to have a brief group discussion to understand how and why different experiences affect researchers' physical activity and well-being. During this session, we will also confirm your step counts from the Mi Fit app. Please do not delete the Mi Fit app installed on your smartwatch before you return your smartwatch.

Kindly indicate which session you would be available to attend through the following link: <<link>>

Refreshments will be served during the session. The session will be audio-recorded to make sure that the researcher will not miss any details discussed during these sessions. The information recorded will remain confidential, and no one else except the researcher will have access to the recordings. The recordings will be destroyed following completion of this research. The identity of the participants will not be disclosed in the research data and the results of this study.

Thank you for your time and commitment towards this research.

Link:

I confirm that I will be able to return the smartwatch and participate in the group discussion on <<dates and times >>

8.3 Appendix C: Research instruments

8.3.1 Pre-intervention survey

Title:
The Impact of Quantified Self Experiences on Researchers' Physical Activity and Well-Being

On a scale from 0 to 10, where 0 is not at all and 10 is very much, please indicate:

1. **How happy do you feel at the present moment?**

   Not at all 0 1 2 3 4 5 6 7 8 9 10 Very much

2. **How satisfied are you with your life nowadays?**

   Not at all 0 1 2 3 4 5 6 7 8 9 10 Very much

3. **Please choose ONE option that best describes your level of physical activity (circle 1 option):**

   a. I currently do not exercise, and I do not intend to start exercising in the next 6 months.
   b. I currently do not exercise, but I am thinking about starting to exercise in the next 6 months
   c. I currently exercise some, but not regularly *(Note: regularly means 3 or more times per week for 20 min or more each time)*
   d. I curently exercise regularly *(Note: regularly means 3 or more times per week for 20 min or more each time)*

4. **Please indicate how you feel about the following statements:**

   a. To me participating in physical activity is .....
   Unenjoyable 1 2 3 4 5 6 7 Enjoyable

   b. Most people like me engage in physical activity
   Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

   c. People like me should engage in physical activity
   Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

   d. I can easily participate in physical activity if I want to
   Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

   e. How motivated are you to participate in physical activity?
   Not at all motivated 1 2 3 4 5 6 7 Extremely motivated

   f. How do you rate your own familiarity with technology?
   Not at all familiar 1 2 3 4 5 6 7 Very familiar

5. **Did you ever use a smartwatch / wearable to track your physical activity in the past?**

   Yes ☐ No ☐

   IF YES: **How much did you trust the smartwatch / fitness activity tracker?**

   Not at all 0 1 2 3 4 5 6 7 8 9 10 Very much

6. **Do you have any fitness app installed on your smartphone that you regularly use to track your physical activity?** Yes ☐ No ☐

   IF YES: **Which app do you use most? _____**

   How much do you trust the fitness activity app?

   Not at all 0 1 2 3 4 5 6 7 8 9 10 Very much

7. **Please answer YES/NO to the following questions:**

In a typical week, do you:	**YES**	**NO**
a. Do voluntary work?		
b. Participate in religious/spiritual activity?		
c. Participate in artistic/creative activity?		
d. Spend time in nature?		
e. Spend time with friends & family?		
f. Get enough rest and sleep?		
g. Maintain a balance between 'work' and 'play'		

8. **Please indicate your level of agreement to the following statements:**

	Strongly Disagree	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**
a. I always pay a lot of attention to how I do things compared with how others do things.					
b. I often compare how I am doing socially (e.g., social skills, popularity) with how other people are doing.					
c. I am not the type of person who compares often with others.					
d. I often try to find out what others think who face similar problems as I face.					
e. I always like to know what others in a similar situation would do.					
f. If I want to learn more about something, I try to find out what others think about it.					
g. I do not care if I hurt people on my way to success.					
h. It annoys me when other people perform better than I do					
i. It is important to treat everyone nicely					
j. I prefer to work with others in a group rather than working alone					

Gender: Male ☐ Female ☐ Other ☐

Age Group:

Under 25 ☐
25 – 29 ☐
30 – 34 ☐
35 - 39 ☐
40 – 44 ☐
45 – 49 ☐
50 – 54 ☐
55 – 59 ☐
60+

Do you have children aged under 16? Yes ☐ No ☐

Are you in a steady relationship? Yes ☐ No ☐

Do you have sufficient income to make ends meet in your household? Yes ☐ No ☐

Height (in cm): _____cm

Weight (in kilos): _____kilos

Nationality: Maltese ☐ Non-Maltese ☐

Employment status (tick all that apply):

Full-time employed ☐
Part-time employed ☐
Full-time student ☐
Part-time student ☐

THANK YOU!

8.3.2 Post-intervention survey

Note: The version below presents the Master version of the survey. An adaptation of the Master survey was presented to each group depending on the game elements included in each treatment.

Title: The Impact of Quantified Self Experiences on Researchers' Physical Activity and Well-Being

On a scale from 0 to 10, where 0 is not at all and 10 is very much, please indicate:

1. **How happy do you feel at the present moment?**

   Not at all 0 1 2 3 4 5 6 7 8 9 10 Very much

2. **How satisfied are you with your life nowadays?**

   Not at all 0 1 2 3 4 5 6 7 8 9 10 Very much

3. **Please choose ONE option that best describes your current level of physical activity (circle 1 option):**

   a. I currently do not exercise, and I do not intend to start exercising in the next 6 months.
   b. I currently do not exercise, but I am thinking about starting to exercise in the next 6 months
   c. I currently exercise some, but not regularly *(Note: regularly means 3 or more times per week for 20 min or more each time)*
   d. I currently exercise regularly *(Note: regularly means 3 or more times per week for 20 min or more each time)*

4. **Please indicate how you feel about the following statements**. **Do you think that**:

   a. Participating in physical activity is …
   Unenjoyable 1 2 3 4 5 6 7 Enjoyable

   b. Most people like you engage in physical activity
   Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

   c. People like you should engage in physical activity
   Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

   d. You can easily participate in physical activity if you want to
   Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

5. **How motivated are you to participate in physical activity?**
   Not at all motivated 1 2 3 4 5 6 7 Extremely motivated

6. **Please answer YES/NO to the following questions:**

In a typical week, do you:	**YES**	**NO**
a. Do voluntary work?		
b. Participate in religious/spiritual activity?		
c. Participate in artistic/creative activity?		
d. Spend time in nature?		

e. Spend time with friends & family?		
f. Get enough rest and sleep?		
g. Maintain a balance between 'work' and 'play'		

7. **Could you please indicate your phone operating system:** iOS ☐ Android ☐

THINKING ABOUT YOUR EXPERIENCE OVER THE LAST MONTH:

8. **How do you rate your overall experience of monitoring your physical activity over the last month?**
   Negative 1 2 3 4 5 6 7 Positive

9. **How motivated were you to participate in physical activity over the last month?**
   Not at all motivated 1 2 3 4 5 6 7 Extremely motivated

10. **For each of the following statements, please indicate how true it is for you:**

	Not at all true						**Very true**
a. I enjoyed doing this experience very much	1	2	3	4	5	6	7
b. I believe this experience was of some value to me	1	2	3	4	5	6	7
c. This experience was fun to do	1	2	3	4	5	6	7
d. I think that doing this experience was useful to increase my physical activity	1	2	3	4	5	6	7
e. I thought this was a boring experience	1	2	3	4	5	6	7
f. I think doing this experience helped me to increase my physical activity	1	2	3	4	5	6	7

11. **How do you rate your overall experience in terms of:**

	Negative						**Positive**
a. Using a smartwatch	1	2	3	4	5	6	7
b. Having a daily target (set on Mi Fit app)	1	2	3	4	5	6	7
c. Gaining points for daily step counts	1	2	3	4	5	6	7
d. Seeing others' performance	1	2	3	4	5	6	7
e. Interacting with others on the app	1	2	3	4	5	6	7
f. Earning badges for your achievements	1	2	3	4	5	6	7
g. Seeing your progress till the next badge	1	2	3	4	5	6	7
h. Participating in weekly competition	1	2	3	4	5	6	7

i.	Ranking on a leaderboard	1	2	3	4	5	6	7
j.	Participating in a weekly challenge	1	2	3	4	5	6	7
k.	Having a shared goal	1	2	3	4	5	6	7
l.	Ranking of teams' performance on leaderboard	1	2	3	4	5	6	7

12. **Do you intend to continue using a smartwatch to monitor your physical activity?**

No chance 1 2 3 4 5 6 7 Certainly

13. **Please indicate your level of agreement to the following statements:**

		Strongly Disagree	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**
a.	In the last month, I have compared my performance on physical activity to others.					
b.	In the last month, I have looked to others' performance to feel better about my performance					
c.	In the last month, I have looked to others' performance and wished I had accomplished what they have accomplished					
d.	In the last month, I have felt envious of someone else's performance.					
e.	In the last month, I have felt as if I am competing with others regarding my performance.					
f.	In the last month, I have felt that one of my goals is to "win" by performing better than others.					

14. **Did you use the idle alert option on your smartwatch to remind you to walk after some time sitting?**

Yes, always ☐ Sometimes ☐ Never ☐

15. **How much did you trust the smartwatch?**

Not at all 0 1 2 3 4 5 6 7 8 9 10 Very much

Participant Code: _____ Weight in kilos: _____

DATE			DAILY STEPS
JAN	30	Thurs	
	31	Fri	
FEB	1	Sat	
	2	Sun	
	3	Mon	
	4	Tue	
	5	Wed	
	6	Thurs	
	7	Fri	
	8	Sat	
	9	Sun	
	10	Mon	
	11	Tue	
	12	Wed	
	13	Thurs	
	14	Fri	
	15	Sat	
	16	Sun	
	17	Mon	
	18	Tue	
	19	Wed	
	20	Thurs	
	21	Fri	
	22	Sat	
	23	Sun	
	24	Mon	
	25	Tue	
	26	Wed	
	27	Thurs	
	28	Fri	
	29	Sat	
MARCH	1	Sun	

THANK YOU!

8.3.3 Semi-structured agenda for focus groups and interviews

Introduction

Moderator to introduce session: confidentiality, open discussion, all opinions welcome, focus on personal experience, there is no right or wrong answer, no mention of names for anonymity.

Introduce and briefly outline topic of discussion:

The Experience of Self-Monitoring of Physical Activity using a Smartwatch and a Gamified App. The aim is to understand ***why*** and ***how*** **the *QSE and* social settings affected users' physical activity and well-being.**

Experience of Self-Monitoring of Physical Activity

If you think about your experience of monitoring your physical activity over the last month:

1. **What are your general views about this experience?** *Unprompted.* **How did this experience affect you?** *Unprompted. Moderator to take note of any positive and negative feedback.*

   Possible Comments – smartwatch helped them quantify their PA, increased their awareness on current PA, increased motivation to engage in PA, *novelty effect wore off after a couple of days, competition / challenge motivated them to increase PA, seeing others' daily steps motivated them to increase PA, being part of a team did not want to fall back,* seeing comments on news feed could motivate them.

2. **What is your opinion / reaction to the following elements?** *Moderator to ask only the elements applicable to each respective group.*

	GROUPS			
Elements	*Yellow*	*Red*	*Blue*	*Green*
a. Smartwatch	✓	✓	✓	✓
b. Target daily step goal on MiFit app (Goal setting & Goal attainment)	✓	✓	✓	✓
c. Points for daily steps		✓	✓	✓
d. Social comparison*		✓	✓	✓
e. Social interaction – messages and likes on News Feed		✓	✓	✓
f. Badges for achievements in daily steps		✓	✓	✓
g. Progression status to achieve next badge		✓	✓	✓
h. Weekly competition		✓		✓
i. Individual leaderboard comapring players' performance		✓		
j. Weekly challenge			✓	
k. Shared Goal			✓	✓
l. Team leaderboard comparing teams' performance				✓

***Note about social comparison:** During the first week, you were not able to see other players' performance, but once competition started other players' daily steps were visible on the news feed. **How did it make you feel that you could see and compare your performance on daily steps with that of others?**

For each element:

a. **WHAT** is your reaction/opinion?

b. **HOW** did it affect your experience? Positive vs Negative? Did you find it useful / beneficial / of value? In what way: fun, enjoyable (emotional); increased awareness, conscious attention (cognitive); social connections / social relatedness (social value); increase in PA, encourage others to participate in PA (Behavioural)

c. **WHY**?

For RED, BLUE and GREEN Group only:

3. **The fact that you did not know the other players (no pre-existing social conditions with other players), did it affect your experience?**

To ALL:

4. **What did you like about this experience?** *Unprompted.*

   Possible benefits could include goal setting, providing feedback on performance, reinforcement, comparing progress, and social connectivity/support.

   .

5. **Is there something that you did not like about this experience? Any features that bothered when you were using these wearables or gamified fitness smartphone apps?** *Unprompted. Moderator to note down any possible negative effects.*

6. **What could have been different or improved in this experience to increase your motivation to engage in PA?** *Unprompted. Moderator to refer to other elements that were not applicable to the group.*

7. **Is there anything else that you would like to add to our discussion that we may have missed or did not mention please?**

Moderator to thank participants and conclude session.

8.4 Appendix D: Supplementary material for quantitative results

Missing step data and step count less than 1K by group and week

Data is presented at participant-day level for each group weekly (20 participants x 7 days per week = 140 participants observations per week for each group).

Missing Values and Step Count less than 1000

	Control	**Competition**	**Cooperation**	**Hybrid**
	Yellow Group	**Red Group**	**Blue Group**	**Green Group**
Week 1				
Missing data	0/140 (0%)	3/140 (2.1%)	1/140 (0.7%)	1/140 (0.7%)
Step count < 1K	1/140 (0.7%)	0/140 (%)	0/140 (0%)	2/140 (1.4%)
Week 2				
Missing data	0/140 (0%)	0/140 (0%)	1/140 (0.7%)	1/140 (0.7%)
Step count < 1K	0/140 (0%)	3/140 (2.1%)	2/140 (1.4%)	3/140 (2.1%)
Week 3				
Missing data	0/140 (0%)	3/140 (2.1%)	0/140 (0%)	2/140 (1.4%)
Step count < 1K	1/140 (0.7%)	2/140 (1.4%)	0/140 (0%)	0/140 (0%)
Week 4				
Missing data	5/140 (3.6%)	9/140 (6.4%)*	2/140 (1.4%)	7/140 (5%)
Step count < 1K	3/140 (2.1%)	5/140 (3.6%)	1/140 (0.7%)	1/140 (0.7%)

*Note: One participant from the Competition group did not record any step counts during week four, and thus no imputation is done in this case and the daily mean step count for week 4 remains as missing data.

Correlation matrix of step counts at different timepoints during the intervention

Correlations

		Baseline	Intervention Time 1	Intervention Time 2	Intervention Time 3
Baseline	Pearson Correlation	1	.847**	.794**	.791**
	Sig. (2-tailed)		<.001	<.001	<.001
	N	80	80	80	79
Intervention Time 1	Pearson Correlation	.847**	1	.830**	.804**
	Sig. (2-tailed)	<.001		<.001	<.001
	N	80	80	80	79
Intervention Time 2	Pearson Correlation	.794**	.830**	1	.831**
	Sig. (2-tailed)	<.001	<.001		<.001
	N	80	80	80	79
Intervention Time 3	Pearson Correlation	.791**	.804**	.831**	1
	Sig. (2-tailed)	<.001	<.001	<.001	
	N	79	79	79	79

**. Correlation is significant at the 0.01 level (2-tailed).

Output results from STATA™

H1: Gamification improves physical activity

Result of Generalized Linear Mixed Effect Model (GLMM) computed using robust standard errors testing H1:

```
Mixed-effects GLM                               Number of obs     =        239
Family:                  Gaussian
Link:                    identity
Group variable:                ID               Number of groups  =         80

                                                Obs per group:
                                                              min =          2
                                                              avg =        3.0
                                                              max =          3

Integration method: mvaghermite                 Integration pts.  =          7

                                                Wald chi2(2)      =     244.32
Log pseudolikelihood = -2148.1735               Prob > chi2       =     0.0000
                                                (Std. Err. adjusted for 80 clusters in ID)
```

InterventionSteps	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
BaselinePA	.80836	.0522878	15.46	0.000	.7058778	.9108423
Gamified	811.4477	384.7748	2.11	0.035	57.30289	1565.593
_cons	1073.25	451.9388	2.37	0.018	187.4657	1959.033
ID						
var(_cons)	1882764	571391.7			1038648	3412898
var(e.InterventionSteps)	2540252	439683.2			1809445	3566221

Mixed-effects GLM — Number of obs = 239
Family: Gaussian
Link: identity
Group variable: ID — Number of groups = 80

Obs per group:
min = 2
avg = 3.0
max = 3

Integration method: mvaghermite — Integration pts. = 7

Wald chi2(6) = 253.69
Log pseudolikelihood = -2142.6941 — Prob > chi2 = 0.0000
(Std. Err. adjusted for 80 clusters in ID)

InterventionSteps	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
BaselinePA	.8090117	.0522108	15.50	0.000	.7066803	.911343
gamified	793.53	458.7774	1.73	0.084	-105.6572	1692.717
gamified						
gamified	0	(omitted)				
InterventionWeek	-408.4143	177.7362	-2.30	0.022	-756.7709	-60.05769
InterventionWeek						
2	241.0571	298.4639	0.81	0.419	-343.9214	826.0357
3	0	(omitted)				
InterventionWeek#gamified						
2#gamified	-.75	472.8313	-0.00	0.999	-927.4824	925.9824
3#gamified	45.69889	468.9888	0.10	0.922	-873.5023	964.9001
_cons	1804.149	609.0449	2.96	0.003	610.4431	2997.855
ID						
var(_cons)	1931543	572422.6			1080554	3452728
var(e.InterventionSteps)	2374086	412085			1689461	3336144

Evidence showing that result remain unchanged when including gender as covariate in the GLMM model testing H1:

Mixed-effects GLM — Number of obs = 239
Family: Gaussian
Link: identity
Group variable: ID — Number of groups = 80

Obs per group:
min = 2
avg = 3.0
max = 3

Integration method: mvaghermite — Integration pts. = 7

Wald chi2(3) = 255.68
Log pseudolikelihood = -2147.9219 — Prob > chi2 = 0.0000
(Std. Err. adjusted for 80 clusters in ID)

InterventionSteps	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
BaselinePA	.8130475	.0515208	15.78	0.000	.7120686	.9140265
gamified						
gamified	772.8487	385.4811	2.00	0.045	17.31964	1528.378
Gender	268.3638	382.0084	0.70	0.482	-480.3589	1017.086
_cons	644.0075	734.0592	0.88	0.380	-794.7221	2082.737
ID						
var(_cons)	1866092	549419.8			1047901	3323121
var(e.InterventionSteps)	2540059	439651.4			1809305	3565954

Evidence showing that results remain unchanged when analysed using panel data random effects regression model:

```
. xtreg InterventionSteps BaselinePA gamified, re vce(robust)

Random-effects GLS regression                   Number of obs     =       239
Group variable: ID                              Number of groups  =        80

R-sq:                                           Obs per group:
     within  = 0.0000                                         min =         2
     between = 0.7558                                         avg =       3.0
     overall = 0.6578                                         max =         3

                                                Wald chi2(2)      =    242.60
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =    0.0000

                                              (Std. Err. adjusted for 80 clusters in ID)
------------------------------------------------------------------------------
             |               Robust
Interventi~s |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  BaselinePA |    .808335   .0524657    15.41   0.000     .7055043    .9111658
   gamified  |   811.5602   386.4048     2.10   0.036     54.22066     1568.9
       _cons |   1073.463   453.7121     2.37   0.018     184.2038    1962.723
-------------+----------------------------------------------------------------
     sigma_u |  1409.9429
     sigma_e |  1593.8999
         rho |  .43898826   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

H2: Hybrid design will facilitate the strongest effect on physical activity

Result of GLMM model computed using robust standard errors testing H2:

Mixed-effects GLM — Number of obs = 239
Family: Gaussian
Link: identity
Group variable: ID — Number of groups = 80

Obs per group:
min = 2
avg = 3.0
max = 3

Integration method: mvaghermite — Integration pts. = 7

Wald chi2(4) = 253.67
Log pseudolikelihood = -2147.9563 — Prob > chi2 = 0.0000

(Std. Err. adjusted for 80 clusters in ID)

InterventionSteps	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
BaselinePA	.81025	.0533465	15.19	0.000	.7056928	.9148071
GROUP						
Cooperation (blue)	637.2907	492.5323	1.29	0.196	-328.0549	1602.636
Hybrid (Team competition - green)	981.6501	524.152	1.87	0.061	-45.66884	2008.969
Competition (red)	817.1174	487.3249	1.68	0.094	-138.0219	1772.257
_cons	1057.076	458.9649	2.30	0.021	157.5212	1956.631
ID						
var(_cons)	1867924	553091.8			1045487	3337334
var(e.InterventionSteps)	2540263	439890.2			1809167	3566801

Result of GLMM model testing H2 including gender as covariate:

Mixed-effects GLM — Number of obs = 239
Family: Gaussian
Link: identity
Group variable: ID — Number of groups = 80

Obs per group:
min = 2
avg = 3.0
max = 3

Integration method: mvaghermite — Integration pts. = 7

Wald chi2(5) = 265.91
Log pseudolikelihood = -2147.7912 — Prob > chi2 = 0.0000
(Std. Err. adjusted for 80 clusters in ID)

InterventionSteps	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
BaselinePA	.8145462	.0521489	15.62	0.000	.7123362	.9167563
GROUP						
Cooperation (blue)	661.6932	488.5516	1.35	0.176	-295.8503	1619.237
Hybrid (Team competition - green)	928.5336	517.7132	1.79	0.073	-86.16558	1943.233
Competition (red)	747.1519	494.5907	1.51	0.131	-222.2279	1716.532
Gender	228.7772	372.9089	0.61	0.540	-502.1108	959.6652
_cons	688.5828	716.5337	0.96	0.337	-715.7974	2092.963
ID						
var(_cons)	1856931	540572.1			1049547	3285409
var(e.InterventionSteps)	2540180	439871.4			1809113	3566672

Evidence showing that results remain unchanged when analysed using panel data random effects regression model:

```
. xtreg InterventionSteps BaselinePA i.GROUP, re vce(robust)

Random-effects GLS regression                   Number of obs     =       239
Group variable: ID                              Number of groups  =        80

R-sq:                                           Obs per group:
     within  = 0.0000                                         min =         2
     between = 0.7571                                         avg =       3.0
     overall = 0.6589                                         max =         3

                                                Wald chi2(4)      =    249.63
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =    0.0000

                                                          (Std. Err. adjusted for 80 clusters in ID)
------------------------------------------------------------------------------
             |               Robust
InterventionSteps |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  BaselinePA |   .8101986   .0537423    15.08   0.000     .7048656    .9155316
             |
       GROUP |
Cooperation (blue) |   637.2725   496.6982     1.28   0.199    -336.2382    1610.783
Hybrid (Team competition - green) |   981.6014   528.6149     1.86   0.063    -54.46488    2017.668
Competition (red) |   817.7495   490.9734     1.67   0.096    -144.5407     1780.04
             |
       _cons |   1057.515   462.6645     2.29   0.022     150.7097    1964.321
-------------+----------------------------------------------------------------
     sigma_u |  1431.0434
     sigma_e |  1593.8999
         rho |  .44631773   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Pre- and post-intervention well-being scores for each group

	PRE		POST	
LIFE SATISFACTION	M	SD	M	SD
Gamified - Competition	6.70	2.155	7.40	2.162
Gamified - Cooperation	6.35	1.843	7.00	1.947
Gamified - Hybrid	7.45	1.317	7.65	1.226
Non-gamified – Control	6.95	2.282	7.30	2.250
HAPPINESS	M	SD	M	SD
Gamified - Competition	7.00	1.747	7.60	2.137
Gamified - Cooperation	6.25	1.803	6.35	1.981
Gamified - Hybrid	7.40	1.142	7.60	1.142
Non-gamified - Control	6.95	2.164	7.30	2.386

ANCOVA results show that after controlling for pre-intervention well-being scores, there are no significant differences in the post-intervention well-being scores of the different gamified experiences and the non-gamified self-tracking group for happiness ($F(3,75) = 0.750$, $p = 0.526$) and life satisfaction ($F(3,75) = 0.183$, $p = 0.908$)

Results from Kruskal-Wallis tests confirm there were no significant differences in the gains reported for happiness ($\chi2(3) = 1.944$, $p = 0.584$) and life satisfaction ($\chi2(3) = 3.066$, $p = 0.381$) between the different types of gamified experiences and non-gamified self-tracking experience.

Output results from STATA™ - Multivariate Linear Regression Models

Regression Model on Happiness Gain

- Enjoyment & interest as significant predictor to Happiness Gain, supporting Hypothesis H5.
- Change in PA is not significant predictor, rejecting Hypothesis 7.

Linear regression

Number of obs	= 80
F(6, 73)	= 4.52
Prob > F	= 0.0006
R-squared	= 0.2946
Root MSE	= 1.4751

W_HappGain	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
W_HAPP1	-.3425925	.1129874	-3.03	0.003	-.5677761	-.1174089
E_IMI_Interest	.6041273	.2714146	2.23	0.029	.0631988	1.145056
E_IMI_Value	.1958994	.1812594	1.08	0.283	-.16535	.5571488
PASOM_Change	-.1335606	.2507643	-0.53	0.596	-.6333332	.366212
PositiveChange	.3979005	.3726137	1.07	0.289	-.3447174	1.140519
X_Gamified	-.0802442	.4640474	-0.17	0.863	-1.005089	.844601
_cons	-2.269874	1.570936	-1.44	0.153	-5.400746	.8609978

Full regression model including demographics and lifestyle control variables

Linear regression

Number of obs	= 80
F(16, 63)	= 4.87
Prob > F	= 0.0000
R-squared	= 0.5330
Root MSE	= 1.529

W_HAPP2	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
W_HAPP1	.6764442	.1605804	4.21	0.000	.3555499	.9973385
E_IMI_Interest	.7175191	.3371023	2.13	0.037	.043874	1.391164
E_IMI_Value	.1359431	.2428091	0.56	0.578	-.3492721	.6211583
PASOM_Change	-.2304757	.2936067	-0.78	0.435	-.817202	.3562506
PositiveChange	.3845676	.3522287	1.09	0.279	-.3193054	1.088441
X_Gamified	-.0334338	.4468285	-0.07	0.941	-.9263492	.8594817
MaleDummy	.0845401	.3815239	0.22	0.825	-.6778746	.8469548
D_YoungAdult	-.2386096	.3686884	-0.65	0.520	-.9753746	.4981554
D_CHILD1	-.3350321	.7538968	-0.44	0.658	-1.841575	1.17151
L_VWORK1	-.1946367	.3788427	-0.51	0.609	-.9516934	.56242
L_RELIGIOUS1	.0937625	.4552155	0.21	0.837	-.8159132	1.003438
L_ARTISTIC1	-.3479998	.609727	-0.57	0.570	-1.566442	.8704424
L_TNATURE1	-.1603083	.3898209	-0.41	0.682	-.9393033	.6186867
L_TFAMILYF1	1.072448	1.193027	0.90	0.372	-1.311626	3.456523
L_WORKPLAY1	-.4574423	.3576907	-1.28	0.206	-1.17223	.2573457
PA_SOMD1	.0533838	.4550789	0.12	0.907	-.8560189	.9627864
_cons	-3.269339	1.979097	-1.65	0.104	-7.224249	.6855709

Regression Model on Life Satisfaction Gain

- Perceived usefulness significant predictor to Life Satisfaction Gain, supporting Hypothesis H6.
- Change in PA is not a significant predictor, rejecting H7.

Linear regression

Number of obs	= 80
F(6, 73)	= 6.78
Prob > F	= 0.0000
R-squared	= 0.4448
Root MSE	= 1.1369

W_LSGain	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
W_SATIS1	-.3341775	.0851437	-3.92	0.000	-.5038687	-.1644862
E_IMI_Interest	.2889132	.2133078	1.35	0.180	-.1362087	.7140351
E_IMI_Value	.4663384	.1416793	3.29	0.002	.183972	.7487048
PASOM_Change	-.1719735	.2615265	-0.66	0.513	-.693195	.349248
PositiveChange	.1395471	.2919858	0.48	0.634	-.4423797	.721474
X_Gamified	.0632184	.4041805	0.16	0.876	-.7423122	.8687489
_cons	-1.675219	1.399019	-1.20	0.235	-4.46346	1.113022

Full regression model including demographics and lifestyle control variables

Linear regression

Number of obs	= 80
F(16, 63)	= 13.72
Prob > F	= 0.0000
R-squared	= 0.7272
Root MSE	= 1.1203

W_SATIS2	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
W_SATIS1	.7500952	.0938321	7.99	0.000	.5625867	.9376037
E_IMI_Interest	.3428599	.212572	1.61	0.112	-.0819313	.7676511
E_IMI_Value	.5374466	.1784831	3.01	0.004	.1807766	.8941165
PASOM_Change	-.2317699	.2709625	-0.86	0.396	-.7732452	.3097055
PositiveChange	.285102	.2960335	0.96	0.339	-.3064738	.8766777
X_Gamified	.0407475	.4026427	0.10	0.920	-.7638698	.8453647
MaleDummy	.0469052	.339296	0.14	0.890	-.6311236	.7249341
D_YoungAdult	-.3869833	.3114812	-1.24	0.219	-1.009429	.2354623
D_CHILD1	-.3487326	.4584079	-0.76	0.450	-1.264788	.5673224
L_VWORK1	.0805254	.2565847	0.31	0.755	-.4322182	.593269
L_RELIGIOUS1	-.4612223	.2999192	-1.54	0.129	-1.060563	.1381184
L_ARTISTIC1	-.1469202	.3513201	-0.42	0.677	-.8489773	.555137
L_TNATURE1	-.4578222	.3161423	-1.45	0.153	-1.089582	.1739377
L_TFAMILYF1	.1671873	.600651	0.28	0.782	-1.033118	1.367493
L_WORKPLAY1	-.5562094	.240875	-2.31	0.024	-1.03756	-.0748591
PA_SOMD1	.3354204	.3355829	1.00	0.321	-.3351885	1.006029
_cons	-2.295818	1.261585	-1.82	0.074	-4.816895	.2252596

8.5 Appendix E: Supplementary material for qualitative findings

Respondents' extracts, codes and themes emerging from the thematic analysis

Theme 1: Self-Tracking of Physical Activity

SELF-TRACKING OF PHYSICAL ACTIVITY			
Sub-theme / Category	**Definition / description**	**Impact:**	**Examples / Extracts**
Being aware and conscious of physical activity	More awareness / consciousness of physical activity Self- reflection – getting to know oneself	Positive	An enjoyable and interesting experience to self-monitor physical activity. Understanding PA patterns e.g. daily average; weekday vs weekend; approximate level of activity during work, hobbies, sports activities etc. Awareness of the sedentary nature of work. Became more mindful and realise that changing minor things in the daily routine affect the level of physical activity.
Feeling driven	Reminder to be more active Challenge oneself to increase physical activity Inspiring behaviour change Influencing others	Positive	Self-monitoring increases the motivation to engage in physical activity and encourages healthy lifestyle habits. Encourage you to do a little bit extra to increase PA Challenge myself to achieve the daily step goal target on the smartwatch. Inspiring behaviour change e.g. taking stairs instead of lift, going for a walk in the evening; take short breaks during work to move; using car less; park the car further away from destination. Influencing others (friends, family, colleagues) to engage in physical activity.
Feeling autonomous	Gives you control Setting own personal goals	Positive	Data on one's performance and behaviour Self-monitoring of physical activity gives you control on setting and achieving your targets. Seeking to achieve the individual personal goals, rather than monitoring others' performance. Feelings of determination to achieve one's goal/target.

			Perceived choice and freedom to set their own goals/ targets.
Feeling accomplished	Feel good factor of achievement Satisfaction feeling	Positive	Monitoring and achieving my target was a positive experience. Prove to myself that I can do it. Rewarding to see a high step count at the end of the day or achieving my target step count earlier during the day. Feeling happy when the smartwatch vibrates when achieving daily target, reaching a high milestone such as 20K steps, getting a badge or seeing their performance on the top part of the leaderboard. Pleasantly surprised that I was doing a lot of steps.
Monitoring one's health	Monitoring one's health using a wearable device	Positive	Positive for monitoring one's health and intend to continue using smartwatch. Enjoyed using the smartwatch to monitor physical activity and other health issues e.g. sleep patterns and sleep quality, heartbeat. Smartwatch reminds user to walk regularly (idle function). A wearable device is more accurate than the smartphone tracker for self-monitoring.

Theme 2: Motivational elements encouraging PA

MOTIVATIONAL ELEMENTS ENCOURAGING PA			
Sub-theme / Category	**Definition / description**	**Perceived Impact:**	**Examples / Extracts**
Immediate and regular feedback	The data and feedback from the smartwatch and its corresponding app	Positive	Immediate and regular feedback on one's performance is motivating. Seeing the step count visible on smartwatch facilitated self-reflection and encouraged people to walk more. The feedback received from smartwatch such as vibration buzz when the target is achieved, or notifications were positive. The smartwatch as a kind of a return loop that gives feedback and motivation. Pushing oneself to achieve more step counts.

Personal goal setting	Having a daily target step count set on the smartwatch Aiming for a Personal Target	Mixed	***Positive***: Daily step goal target encouraged people to walk more. Conscious effort to do activities until the daily target is achieved. Rewarding to see that one is exceeding the target and/or achieving target quicker than expected. Challenge oneself to increase target goal. ***Neutral:*** Despite not achieving the daily target on most days, it didn't influence negatively. Neutral to the daily target (participants had an active lifestyle and constantly reached 10K steps.) People who are not target-oriented felt that the target did not affect them. ***Negative:*** Some felt daily target is limiting their freedom, so they set it to a low step count target. Some felt bad if they do not achieve the target.
Social comparison	Seeing others' performance Social comparison	Mixed	***Positive:*** Seeing the steps of others was motivating and interesting. Social comparison through the leaderboard – competing with the one ahead on the leaderboard. More motivating than doing it on your own. It is good to have something to benchmark with. Felt proud and happy when progressing well on the leaderboard ranking. ***Neutral:*** Did not compare with others. Seeing others do very high step counts was not discouraging. It did not influence me because we have different lifestyles. Looked at others' performance but it did not change my behaviour. ***Negative:*** Seeing others walk so much more than me, I felt it was pointless competing and lost interest.

Competitive element	A competitive setting involving a competition amongst participants	Mixed	***Positive:*** Competitiveness facilitated motivation to walk more particularly the leaderboard ranking. Did an effort to reach someone who was ahead of me in the competition. Compared with people who were in my range of step counts. Competition with friends would be more engaging. ***Neutral:*** Some participants were not into the competition aspect with others and focused more on personal self-monitoring. ***Negative***: Demotivating if others are too far off. Prefer to have people in the same range of physical activity or same lifestyles. Perceptions of a fair competition are essential. Added pressure, life is already too competitive
Cooperative element	A cooperative setting involving a shared group challenge amongst participants	Mixed	***Positive:*** Nice when the challenge is accomplished, and people cooperate as a team. Seeing somebody do so well in a cooperative design is nice, but it's different if it is in a competitive setting. Group cohesion helps in cooperating together. The pirate challenge was cute. ***Neutral:*** Some participants were not interested to participate in the challenge. ***Negative***: Social loafing. Keen players felt disappointed and frustrated when seeing others not making an effort.
A sense of community spirit	Group cohesion & social bonds **Team experience**	Positive	Being part of a team can be motivating. Social connections improve community spirit. Group cohesion could have improved team experience.
Enticing new experiences	Novelty element	Mixed	The experience was fun and interesting, but it was fading off over time.

			When competition started, the interest went up again but after a while it was not that exciting. Eager at the beginning but then there was disparity in steps amongst participants and lost interest after a few days. Out of curiosity, there was interest in the first few days to see what was going to happen, then it was becoming part of a routine, nothing new. Needs to have something to aspire for.
Gratifying reward	Provide recognition for the participants' efforts, progression and achievements	Positive	Seeking a meaningful reward to aspire for. Trying it out to see whether the experience translates into getting a tangible reward such as pizza, chocolate, or a gift voucher. An intangible reward like exclusivity, unlockable game elements and features and unique status within the app are also meaningful for some participants. Immediate feedback as a congratulations message after achieving target or completing a challenge is also rewarding. Seeing progress on the leaderboard Badges were like a personal achievement… a good reward. It gives you a good feeling when you achieve a badge. Badges were fun. Kept going until the last badge which reflects high performance of physical activity was achieved. ***Neutral*:** Badges did not influence all the participants - Some participants did not make an extra effort to walk more even though they were close to achieve the badge.

Theme 3: The value of social engagement and group cohesion

THE VALUE OF SOCIAL ENGAGEMENT AND GROUP COHESION			
Sub-theme / Category	**Definition / description**	**Impact:**	**Examples / Extracts**
Identifiability	Disclosing the user identity such as name and gender instead of anonymity Non-anonymity	Positive	Anonymity makes it impersonal - the fact that you don't know your teammates or opponents, kind of takes away the competitive and also the cooperative aspects and the buzz of the game. It would be fun if it is not anonymous and doing it with people you know. Interaction was less since it was anonymous. Willing to disclose identity, better than anonymous. It would motivate participants more and made more effort. Only 1 person mentioned in favour of anonymity due to feeling pressure and others' expectations.
Social connections	Social bond or connections e.g. friends, colleagues or family members	Positive	Social connections enhance group cohesion Participants seek social connections even though personal goals are prioritised. Doing it with people I know (friends/colleagues/family) would have made a difference, it would be more engaging. Participants seek social connections in a group experience, even though they prioritise personal goals. Doing the challenge / competition with friends or people I know with whom there is a social bond is more interesting, engaging, intense, and motivating. If you have a social connection with the people, there will be more interaction and friendly teasing. It would be more fun, and the effect of the competition or challenge will be felt much stronger. In the case of a cooperative designs, there will be more possibility of collaboration amongst friends.

			In the case of a competitive design, it would be more competitive and more engaging. If I don't know the people, I don't care about monitoring their performance, there is no social bond.
Opportunities for social interaction	Seeking opportunities of meeting other group members in person	Mixed (Mostly in favour of social interaction, some against)	***Positive***: Eager to meet up socially. Meeting others in person (e.g. session at the gym or for a drink) facilitates group cohesion. Social interaction would have helped in getting to know each other and work together to achieve the shared goal. ***Negative:*** Meeting others would be added pressure because they will have expectations from me.

8.6 Appendix F: Additional analysis

Individual traits associated with physical activity

Step count data gathered through the wearable physical activity trackers was analysed together with the self-reported data gathered through the questionnaires to identify the individual traits associated with physical activity. The dependent variable for this analysis was the mean daily step count (a continuous variable) for each respondent calculated as the average of the step counts recorded through the physical activity trackers during the experimental study. The mean (SD) for the participants' daily step count was 8387 (SD = 3338). The independent variables considered for this analysis were potential predictors identified in literature (Biddle & Mutrie, 2007; Briguglio, 2019; Cortis et al., 2017; Dishman et al., 1985; Eyler, 2003) associated with the adoption and maintenance of physical activity. These include demographic and lifestyle variables, as well as psychological factors, including attitude, subjective norms, perceived behavioural control, behavioural intention, and subjective wellbeing.

Statistical analysis was performed in three phases. First, the descriptive statistics were computed for the sample characteristics and the potential predictors of physical activity. Means and standard deviation were presented for continuous variables, and frequencies and respective percentages were presented for the categorical variables. The sample characteristics in terms of the demographic and psychographic variables are presented in Table F1. The pairwise correlations for all the potential predictors with the dependent variable were computed to check for the assumption of no multicollinearity.

Second, a univariate linear regression analysis was carried out for each potential predictor of physical activity (see Table F2). The analysis identified age, having children under the age of sixteen, spending time in nature, attitude towards physical activity, descriptive subjective norms, perceived behavioural control and behavioural intention as significant predictors to physical activity (mean daily step count). These variables had a p-value of less than 0.1 and were retained for further analysis. This approach reflects a purposeful selection of variables in the regression modelling process.

Finally, the remaining factors were included in a multivariate linear regression model using backward elimination using a cut-off p-value of 0.10. Table F2 presents the unstandardized regression coefficients (β), standard error of the coefficients, 95% confidence interval and the p-values. Results from the multivariate regression model show that having children under sixteen years (β = 1926; 95% CI: 300 to 3551), the individual's attitude towards physical activity (β = 563; 95% CI: -72 to 1199), and the behavioural intention (β = 515; 95% CI: -54 to 1085) are statistically significant predictors for physical activity (mean daily step count). As assessed by a Durbin-Watson statistic of 2.043 there was independence of residuals. There was no evidence of multicollinearity as assessed by tolerance values greater than 0.1. There were no leverage values greater than 0.2, and none of the Cook's distance values were above 1. The assumption of normality was met as assessed by a Q-Q plot. The multiple regression model statistically significantly predicted physical activity, $F(3,76) = 7.464$, $p < 0.001$, adjusted R squared = 0.197. Data analysis was carried out using SPSS 27.

Table F1: Sample characteristics

Sample characteristics			
Individual traits		**Lifestyle variables**	
Gender		Do voluntary work, n (%)	19 (24%)
Male, n (%)	35 (44%)	Participate in religious/ spiritual activity, n (%)	25 (31%)
Female, n (%)	45 (56%)	Participate in artistic/ creative activity, n (%)	16 (20%)
Age groups		Spend time in nature, n (%)	49 (61%)
Young adulthood (20 - 34 years)	42 (52%)	Spend time with friends & family, n (%)	77 (96%)
Middle aged (35 - 54 years)	36 (45%)	Get enough rest and sleep, n (%)	51 (64%)
Older adulthood (55+ years)	2 (3%)	Maintain a balance between 'work' and 'play', n (%)	40 (50%)
Nationality		**Psychological variables** *(see note b)*	
Maltese, n (%)	61 (76%)	Attitude towards physical activity, mean (SD)	5.68 (1.30)
Non-maltese, n (%)	19 (24%)	Descriptive subjective norms, mean (SD)	4.41 (1.49)
Employment status		Injunctive subjective norms, mean (SD)	6.50 (1.03)
Full-time employed, n (%)	52 (65%)	Perceived behavioural control, mean (SD)	5.39 (1.43)
Part-time employed, n (%)	17 (21%)	Physical activity behavioural intention, mean (SD)	5.11 (1.43)
Full-time student, n (%)	27 (34%)		
Part-time student, n (%)	26 (33%)	**Individuals' subjective well-being** *(see note c)*	
Have children under 16 years, n (%)	18 (23%)	Life satisfaction, mean (SD)	6.86 (1.94)
Have a steady relationship, n (%)	58 (73%)	Happiness, mean (SD)	6.90 (1.77)
Have sufficient income, n (%) *(see note a)*	70 (89%)		
BMI pre-intervention mean (SD)	25.25 (4.62)		

Notes: N= 80

Note a: 1 respondent provided no data to the question related to income.

Note b: Pyschological variables measured on a 7-point likert scale (1-7)

Note c: Well-being variables measured on an 11-point likert scale (0-10)

Table F2: Results from the univariate and multivariate regression of potential predictors of physical activity

		Univariate Linear Regression				Multivariate Linear Regression					
Variable	**Reference**	***β***	**SE**	**t**	**p-value**	***β***	**SE**	**t**	**p-value**	**95% CI**	
Gender	Male	556.92	754.43	0.74	0.46						
Age	Young adulthood	**-1262.86**	**738.35**	**-1.71**	**0.09**						
Nationality	Maltese	133.47	882.40	0.15	0.88						
Employment Status	Full time employed	-389.01	786.16	-0.49	0.62						
Children under 16 years		**2202.05**	**864.12**	**2.55**	**0.01**	1926.04	816.04	2.36	0.02	300.75	3551.32
Steady relationship		274.59	840.52	0.33	0.74						
Sufficient income		886.05	1189.02	0.75	0.46						
BMI		-7.82	81.83	-0.10	0.92						
Voluntary Work		-67.33	882.50	-0.08	0.94						
Religious/Spiritual activity		-171.28	810.02	-0.21	0.83						
Artistic/Creative activity		-825.72	934.24	-0.88	0.38						
Time in nature		**1400.10**	**754.42**	**1.86**	**0.07**						
Time with family & friends		1910.38	1964.95	0.97	0.33						
Enough rest & sleep		350.35	780.24	0.45	0.65						
Balance work & play		315.00	750.28	0.42	0.68						
Happiness		212.68	212.29	1.00	0.32						
Life Satisfaction		292.99	191.91	1.53	0.13						
Attitude towards PA		**982.79**	**268.53**	**3.66**	**0.00**	563.99	319.33	1.77	0.08	-72.01	1200.00
Descriptive subjective norms		**433.03**	**248.86**	**1.74**	**0.09**						
Injunctive subjective norms		343.82	364.44	0.94	0.35						
Perceived behavioural control		**479.11**	**259.13**	**1.85**	**0.07**						
Behavioural intention		**803.79**	**247.74**	**3.24**	**0.00**	515.36	286.28	1.80	0.08	-54.80	1085.53
Constant						2118.27	1572.68	1.35	0.18	-1014.00	5250.54
						Model: R = .477; R squared = .228; adjusted R squared =.197; Std. Error of the Estimate = 2990.870; Durbin-Watson = 2.043.					

Notes: Model = 'Backward' method in SPSS; β = unstandardised regression coefficients; SE = Standard error of the coefficients; CI = Confidence Interval; PA = Physical Activity.

8.7 Appendix G: Presentations and publications

Parts of this thesis have already been published in peer-reviewed journals or have been presented at peer-reviewed conferences. These contributions are the following:

1. Grech, E. M., Briguglio, M. & Said, E, (2019). Gamification as an Engagement Marketing Strategy. *Academy of Marketing Conference 2019*, London.

2. Grech, E. M., Briguglio, M., & Said, E. (2019). Contributing to value creation through gamification as engagement marketing. *JAMS Thought Leaders' Conference on Innovating in the Digital Economy: Leveraging Technology to Create Value for Consumers and Firms*, Milan.

3. Grech, E. M., Briguglio, M. & Said, E. (2020). How do gamified quantified self experiences increase physical activity and well-being? Competitive, collaborative and coopetitive treatments. *SABE 2020 International Conference on Experimental and Behavioural Economics*, Moscow.

4. Grech, E. M., Briguglio, M., & Said, E. (2023). Self-tracking and gamification of physical activity: Effects on wellbeing. CEUR-WS, In *Proceedings of the 7th International GamiFIN Conference (GamiFIN 2023)*, v.3405, Levi, pp. 119–131.

5. Grech, E. M., Briguglio, M., & Said, E. (2024). A field experiment on gamification of physical activity – Effects on motivation and steps. *International Journal of Human-Computer Studies*, 184, 103205. https://doi.org/https://doi.org/10.1016/j.ijhcs.2023.103205

6. Grech, E. M., Briguglio, M., & Said, E. (2024). Protocol for a randomised controlled field experiment on the effect of different gamification designs of physical activity. *MethodsX*, *12*,102551.