The Impacts of Gameful and Interactive Technologies on Hindering or Promoting Self-regulation

by

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Examining Committee Membership

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AUTHOR'S DECLARATION

This thesis consists of material all of which I authored or co-authored as the first and corresponding author: see Statement of Contributions included in the thesis.

This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

STATEMENT OF CONTRIBUTIONS

This thesis to some extent consists of work done in collaboration with a few other authors. The following paragraphs describe the parts in the dissertation that Milad Soroush has been a sole author of and the parts that are the result of collaborations mainly towards published or working papers, in which Milad Soroush has been the first and corresponding author.

The collaborative work presented in the thesis is included in published papers or will be included in working papers for future submissions, which are as follows:

- Soroush, M., Hancock, M., & Bohns, V. K. (2014, October). Self-control in casual games: The relationship between Candy Crush Saga™ players' in-app purchases and self-control. In 2014 IEEE Games Media Entertainment (pp. 1-6). IEEE. *(published paper)*

- Soroush, M., Hancock, M., & Bohns, V. K. (2018, October). Investigating Game Mechanics that Target Players' Self-Control While Maintaining Engagement. In Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play (pp. 489-502*). (published paper)*

- Soroush, M., Hancock, M., & Bohns, V. K. (2021) Resisting Tempting Foods with Image Filters: The Effects of Saturation and Framing on Hedonic Experiences. *(working paper)*

- Soroush, M., Hancock, M., & Bohns, V. K. (2021) The Effect of Framing Photos on Perceived Psychological Distance and Abstraction. *(working paper)*

- Soroush, M., Hancock, M., & Bohns, V. K. (2021) Battling Tempting Foods Using Saturation and Distancing Techniques: A Longitudinal Study. *(working paper)*

Note that the descriptions of working papers, including their titles, are subject to change in the future.

ABSTRACT

Self-regulation is the essential component of goal pursuit that allows us to make better decisions and resist temptation of unwanted desires, which ultimately impacts our well-being. It is essential to identify and understand factors that hinder or facilitate our successful self-regulation that have the potential to improve people's competency to effectively self-regulate their thoughts, emotions, and behaviours.

Interactive media technologies, specifically games, present environments that could greatly affect self-control and self-regulation processes for better or for worse. Despite the considerable impact of rapidly changing technologies on self-regulation, the relationship between design aspects of technologies and self-regulation or self-regulation improvement are not well studied.

The downside of the rapid pace of modern technological advancement is constantly encountering new phenomena that could hinder self-regulation mechanisms, without these phenomena being properly studied. On the other hand, such advancements provide a compelling opportunity to design interactive technologies to help people improve their self-control and self-regulation. Specifically, there is great potential of media technologies to shape our motivations and the ways we experience the world (e.g., our visual experience), which increases the appeal and importance of exploring the connection between interactive technologies and self-regulation, especially with respect to self-regulation improvement, which is the primary focus of this thesis.

I first investigate how design elements can impact self-regulation success or failure in a widely used yet underexplored phenomenon of *free-to-play* games. In chapter 3, I present a correlational survey study (Study 1) that explores the connection between free-to-play games and their impact on self-regulation. The findings of the study indicate a relationship between

trait self-control and players' in-app purchasing decisions. It also identifies players' self-regulation struggles and failures when playing such games.

I then explore improving a person's self-regulation through increasing their capacity for self-control. In chapter 4, I present the design and implementation of a self-control game to investigate how we can use gameful interactive technologies to improve cognitive control. I also present an empirical study (Study 2), which shows the potential of using self-control games to engage players without creating a negative player experience or undermining intrinsic motivation. In chapter 5, I provide a commentary on the resource model of self-control (i.e., ego-depletion research) and controversies surrounding the topic. The commentary provides a critical review of current state of research and a possible approach to tackle the issue.

I next demonstrate and evaluate the need for a broader approach to improving self-regulation of desires and behaviours in a series of three experimental studies. I first discuss the importance of adopting broader approaches that can directly target and improve self-regulation mechanisms. In chapter 6, I provide a critical review regarding the role of psychological distance in understanding self-regulation and self-regulation mechanisms and its potential for new insight to create novel interactive technologies that is explored in the next experimental studies (Studies 3-5).

In the following chapters 7-9, I therefore highlight a need for broader approaches for improving self-regulation of desires and behaviours, which encompasses a series of experimental studies to implement and test simple interaction techniques to boost and improve self-regulation. In chapter 7, I present a pre-registered online experiment (Study 3) that explores the possibility of impacting perception of temporal distance and abstraction through simple design considerations such as using a framing effect, the results of which did not reveal a considerable impact of the framing effect on temporal distance and on abstraction.

Notably, I found contradictory evidence to what is presented by construal-level theory on the relationship between abstraction and psychological distance.

In chapter 8, I present a lab experiment (Study 4) to study another simple interaction technique to distance tempting foods through saturation and framing effects using tablet technologies, the results of which show the effectiveness of using saturation to reduce temptation and unwanted desires by visually mediating the experience of tempting palatable food items.

In chapter 9, I present the design of a mobile application for testing the use of the saturation effect and increasing the perception of distance directly in a mobile application. I then present a pre-registered longitudinal experiment (Study 5) that explores the effectiveness of this technology and the interaction techniques in a more realistic environment. The findings revealed preliminary evidence of the effectiveness of design features and interaction techniques such as changing saturation and perceived distance of tempting food items.

Overall, the focus of the research presented in this thesis has been on the connection between design and self-regulation and self-regulation improvement, and particularly, in using interactive technologies and simple interaction techniques to help people improve their self-control and self-regulation, and ultimately achieve their goals.

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Chapter 1
Introduction

Self-regulation is the critical component of effective goal pursuit. It allows us to make better, more mindful choices, and is associated with affective well-being and happiness in life (Baumeister et al., 1994; Hofmann, Luhmann, et al., 2014). Self-regulation has been used as an umbrella term that encompasses a number of related constructs, such as self-control (Baumeister et al., 1994), delay of gratification (Mischel et al., 1989), impulse control (Tangney et al., 2004a), cognitive control (Hofmann, Schmeichel, et al., 2012), and conscientiousness (Moffitt et al., 2011). A key question for scientists is identifying factors that can help people to regulate their desires and behaviour more effectively to, for example, achieve academic goals, create healthy choices and habits, prevent unethical behaviour, resist drug or alcohol consumption, avoid excessive use of media, et cetera.

The importance of research that can help us understand how we can improve self-regulation is made clear by remarkable findings on the effect self-regulation has on numerous positive outcomes in life. In one of the original studies of self-regulation, which focused specifically on the construct of delay of gratification, measured by the now well-known "Marshmallow Test", Mischel et al. (1989) demonstrated that the ability of preschoolers to wait for a desirable treat predicted numerous positive outcomes and achievements later in life, including interpersonal success, academic achievement, and SAT scores at a 12-year follow-up to the study (Mischel et al., 1989). Even more astounding, at a 40-year follow-up, these same measures continued to predict participants' cognitive control (Casey et al., 2011; Eigsti et al., 2006). Moffitt et al. (2011) corroborated these findings in a larger sample of 1000 people, finding that self-control aptitude in childhood, measured as conscientiousness in this study, predicted a wide variety of outcomes in life domains such as health, finance, and criminality all

the way up to the age of 32. Given these findings, it seems plausible that even a very small shift in a person's aptitude and competence for self-control and self-regulation could have a variety of important, long-term positive outcomes (Moffitt et al., 2011).

It is essential to identify and understand factors that set back or facilitate our goals pursuit. Interactive media technologies, specifically games, present a compelling opportunity for people to engage in tasks to study, measure and boost self-regulation. Despite the promising nature of games and other technologies for self-regulation interventions, using such interactive designs has been limited to a small number of studies for improving capacity for cognitive control without focusing on design aspects, or focusing on improving self-regulation of behaviour in everyday life through basic goal-setting or goal-monitoring approaches, which do not fully or sufficiently harness the potential of using such technologies for self-regulation improvement (e.g., see: Anguera & Gazzaley, 2015). Similarly, as gameful interactive designs and gamification techniques are becoming more sophisticated, we tend to underestimate the complexity of their possible negative impacts on people's experience and how they can hinder their well-being and healthy decision making. Therefore, we need a better focus on investigating design aspects of media technologies and the experience of people in using them in order to help them mitigate the negative effects and utilize such technologies' potential for self-regulation improvement.

Accordingly, our best knowledge of self-regulation improvement also comes from similar studies that are mostly limited to providing different instructions to participants to investigate those methods (e.g., instructing participants to avoid eating sweets for a few weeks; Muraven, 2010), rather than practicing self-regulation strategies and their corresponding mental operations.

Altogether, this research aims to better identify and investigate factors and approaches that hinder or promote self-regulation when using interactive and gameful technologies. This is

particularly important as technologies are becoming an increasingly inseparable part of our lives through which we experience the world and engage with it. This research includes examining both positive and negative impacts of interactive technologies and design considerations, but heavily focuses on how we can use technologies to affect self-regulation processes and achieve our goals. I will argue later that it is important for us to focus on improving broad cognitive-control capacities and self-regulation competencies, and this goal can be achieved through interactive designs that facilitate practicing self-regulation processes than are traditionally targeted in self-control practices or behaviour change interventions.

Preliminary Definitions

In this section, I provide definitions of the terms self-regulation, self-control and cognitive control to explain the main problems and research questions in this thesis. In Chapter 2, I explore these definitions in more depth, especially with respect to the importance and implications of having a better conceptualization of self-control and self-regulation.

The term self-regulation is often used interchangeably with self-control. In this thesis, self-control refers to overriding and altering lower-order processes, such as impulses, urges, or responses in favour of higher-order processes to reach a desired, relatively long-term, goal or state, which describes a subset of broader self-regulatory processes that are involved in goal pursuit and help us achieve our desired states (Hofmann, Schmeichel, et al., 2012). On the other hand, cognitive control, specifically refers to higher order cognitive processes that allow us to govern the mental processes involved in goal pursuit (also referred to as executive functions), including working memory, impulse control, and task switching functions (Diamond, 2013).

Problems and General Research Questions

The content of this research is mostly regarding identifying phenomena and approaches that negatively or positively impact achieving our goals and designing and testing interactive experiences for improving self-regulation of desire and behaviour. The topics of study involve various contexts and domains such as cognitive functions, desire experience, eating behaviour, and purchasing decisions. Three overall problems and their corresponding high-level research questions are discussed later in this chapter.

As technological advancements progress, design models and techniques are rapidly changing that require investigating how new phenomena have positive or negative impacts on the self-regulation of desires and behaviours. To begin, I investigated how design elements such as free-to-play game models can impact self-regulation success or failure, with a specific focus on their impact on players' decisions and whether they hinder their ability to self-regulate. We can use this knowledge to identify how these elements affect player experience and also help designers to create an experience that helps people to more effectively regulate their behaviour when playing these games (see Problem 1).

While this knowledge is helpful for researchers studying the connection between design mechanics and self-regulation success or improvement, I chose to explore approaches that use interactive technologies and interaction techniques to directly improve self-control and self-regulation. Therefore, I focused on new designs that could be integrated with current technologies. The primary avenues to achieve this goal are improving cognitive control and self-control processes (see Problem 2) or improving self-regulation strategies (see Problem 3). I decided to first focus on creating and testing self-control games that could target cognitive control in individuals, which could ultimately improve their ability to better regulate their behaviour and achieve their goals. Designing interactive technologies that could properly target self-control processes presents challenges that are also the focus of this research. Additionally, there are theoretical challenges surrounding the topic that I decided to explore through critical review of the current state of research about self-control and self-control

improvement (see Problem 2).

While designing technologies that effectively target self-control processes could have major benefits for individuals, there is limited knowledge in how researchers can use design elements and techniques to target these broader self-regulatory functions and strategies that help us achieve our goals, especially when we consider individuals facing strong and unwanted desires or temptations (See Problem 3). Therefore, I chose to explore designing and testing simple interaction techniques with the goal of ultimately designing and testing an interactive technology that could help people regulate their desires and behaviours specifically in the context of facing tempting foods.

A detailed discussion of these problems and their related research questions are as follows:

Problem 1: Understanding the impact of free-to-play game designs on hindering self-control

The situations in which our experience or behaviour may be negatively impacted when using interactive technologies have previously been studied, including how using smartphones or various forms of media could negatively impact people's experience or well-being. However, we are continuously encountering new phenomena that demand researchers' attention. In-app purchases in freemium (free-to-play) business models are becoming the most successful models to generate revenue in game apps. The amount of money spent on these games has made them among the top grossing games, while they are advertised to be free-to-play for all players (Brockes, 2014; Wingfield & De La Merced, 2014). These games are usually designed using a wide range of gamification elements and techniques to keep players engaged with the game, for example, to make progress and win the game. At the same time, making progress or being able to compete at the same level as other players in some of these games could significantly depend on how much money is spent in the game.

While there is a connection between purchasing decisions and self-regulation success or failure in free-to-play games, it is unclear if self-regulation failure is what the nature of that connection is. Therefore, we do not know how strong that connection is or how the freemium model plays a role in it.

Problem 2. Understanding the potential of games for improving self-regulation.

Despite the promising nature of games for self-regulation interventions, using such interactive designs has been limited to a small number of studies for improving the capacity for cognitive control without focusing on design aspects of a self-control game, or focusing on improving self-regulation of behaviour in everyday life (Anguera & Gazzaley, 2015).

In addition, there are controversies surrounding the hypothesis that self-control can be improved simply by practicing a self-control task (Inzlicht et al., 2014; Inzlicht & Berkman, 2015; Melby-Lervåg et al., 2016; Melby-Lervåg & Hulme, 2013). In particular, it is highly debated whether the benefits of practicing one domain of self-control transfers to other domains (Anguera & Gazzaley, 2015; Hofmann, Schmeichel, et al., 2012; Melby-Lervåg et al., 2016; Melby-Lervåg & Hulme, 2013) or helps to increase an overall limited resource or behaviours (Carter et al., 2015; Carter & Mccullough, 2014; Carter & McCullough, 2013; Inzlicht & Berkman, 2015; Miles et al., 2016). For example, while working memory and inhibitory control are both considered related to self-control, it is uncertain whether exercising working memory, in and of itself, has any effect on a different domain or whether it increases a cognitive capacity that helps self-control generally. This poses a particular conundrum for designing a gameful task for practicing self-control, as at the core of that idea is the need to transfer this learned exercise outside of the task being used. Therefore, we cannot claim that we possess activities or platforms that can effectively improve cognitive control or more

general self-control processes.

Constructing and studying an activity or platform that can challenge cognitive control processes could significantly help with these issues but presents a number of challenges. For example, tasks that require using cognitive control and effortful inhibition of responses are mentally taxing and possibly depleting (Baumeister et al., 2007a; Finkel et al., 2006; Hagger et al., 2010; Molden et al., 2012; Muraven et al., 1998), which can negatively impact a player's experience. A game that requires considerable self-control might simultaneously create negative affect, decrease motivation, or result in disengagement from the task. Therefore, we need to first study cognitive-control games before using them as tasks for self-regulation improvement. Also, we need a more in-depth theoretical understanding of how we can use games to improve the capacity for cognitive control and possibly self-regulation in general.

More specifically, the research questions that are explored in chapter 4 and 5 are: (1) can we significantly target a player's cognitive capacity for self-control without affecting other important factors of a positive player experience, such as causing disengagement or negative affect, (2) can cognitive-control practice fundamentally change the capacity for better self-regulation of behaviour, and (3) can we provide a different understanding of current theoretical framework for self-control improvement such as the ego-depletion (resource) model and ultimately more successfully study and design self-control and self-control improvement.

Problem 3: Understanding how interactive technologies can be used to decrease desire, in addition to offering self-regulation practice.

While cognitive control is an important aspect of our brain functions that facilitate goal pursuit, the large body of other mental operations and cognitive competencies are more directly related to how effectively we regulate our emotions and behaviours (Duckworth et al., 2016a;

Mischel, 1974; Myrseth & Fishbach, 2009a). Researchers have not focused on designing interactive experiences that can facilitate practicing self-regulation improvement. Interactive technologies provide the possibility of creating a variety of simulated situations that would allow individuals to practice self-regulation techniques—which have the potential to introduce advanced designs for self-regulation interventions. There are advantages to using such simulations. For example, in an experience provided by an interactive design, people are able to practice strategies and corresponding mental operations and learn to implement them in similar situations.

Most psychological approaches have focused on improving self-regulation of behaviour by helping people implement their intentions more successfully through better goal setting, monitoring their goal progress, and other aspects that affect the implementation phase of self-control (Inzlicht et al., 2014). Such approaches do not highlight various possibilities of intervening in how people visually perceive the world, for example, how the hedonic experience of what people visually perceive is relevant to the quality and strength of their motivation to approach or avoid a tempting situation, object, or behaviour. Recently, researchers have been more focused on the significance of strong or unwanted *desire* and *temptation* on successfully regulating a goal-relevant behaviour (Hofmann, Adriaanse, et al., 2014; Hofmann, Baumeister, et al., 2012; Hofmann & Van Dillen, 2012; Kavanagh et al., 2005; Milyavskaya & Inzlicht, 2016) identifying desire regulation as an important factor of behavioural change in many domains (Hofmann & Van Dillen, 2012).

There are a wide range of studies that explore the design and impact of using technologies in behaviour change. For instance, HCI research has focused on the topic of *persuasive technologies* (Fogg, 2009) to influence people's behaviour through various technologies and especially videogames (e.g., see: Bogost, 2007). This field has increasingly focused on promoting people's well-being and healthy behaviour (Orji & Moffatt, 2018). For example, studies have investigated promoting physical activities using on-body sensing technologies

(Consolvo et al., 2008) or interactive computer games (Lin et al., 2006). Studies have also focused on other important behaviours such as promotion of healthy eating by, for example, providing daily feedback to improve goal pursuit or educating people through casual games (Pollak et al., 2010, Orji et al., 2012), and prevention of risky behaviour through persuasive computing (Rosser et al. 2010).

There are many studies that focus on behaviour change through various self-regulation processes. Yet, comparable studies that have explored the potential of technologies for impacting these processes have similarly focused mostly on helping regulate behaviour by tracking the goal progress or increasing motivation to pursue goals. For example, they focus on tracking eating behaviour goals (for a review, see: Lyngs et al., 2019; Pinder et al., 2018), with no particular focus on the impact of hedonic experiences of temptation on the effectiveness of these methods and no focus on how we can practice various mental operation that could help people reconstrue the situation and maintain their motivations. Therefore, two major issues that are not explored enough and are being addressed in this research are (1) underestimating the importance of experiential factors such as desire and temptation experience and designing technologies that specifically address those problems, and (2) lack of a more systematic approach that explains wider range of phenomena and methods regarding how we can use technologies to effectively apply them for intervention.

More specifically, the research questions related to this problem that are being explored to address the aforementioned topics are: (1) Can we identify the experience of strong unwanted desires and temptations as an essential factor that determines the success of self-regulation interventions? For example, could we use interactive technologies as a tool to assist behaviour change, for example, when pursuing goals related to healthy eating or purchasing decisions, by decreasing the appeal of the desired object or temptation? (2) In order to decrease the appeal of unwanted temptations to facilitate behaviour change, can we draw from systematic approaches to self-regulation, for example by identifying psychological

distance as a central factor that could be used to facilitate and improve self-regulation? (3) Can we use different forms of psychological distance (e.g., temporal, hypothetical, or emotional distance) to inform designs to assist self-regulation such as mediating people's perception of the situation when using simple technologies such as their phone or computer to distance a tempting object or situation and make better decisions or behave accordingly with their goals?

Scope of the research

The thesis involves research questions directly related to the field of human-computer interaction and psychological science. It contributes to these fields of research by exploring new approaches interactive technologies can use in order to promote self-regulation of desire and behaviour.

The fields of psychology and human-computer interaction overlap in many domains, as human-computer interaction deals with a variety of topics surrounding technological designs and their influence on our experience, emotions, and behaviours, which is a main focus of psychological science study. For example, motivational theories such as self-determination theory have been widely used to study and impact people's experience when interacting with technology (Przybylski et al., 2010; Ryan et al., 2006). In addition, games user research (GUR) and gamification research often investigate the design, use, and impact of games or gamification (i.e., using gameful designs by incorporating partial elements of a game) on changes in peoples' motivation and behaviour (Deterding et al., 2011). Using interactive technologies to impact self-regulation and self-control has also been part of psychological science research. For example, researchers have previously used games to measure and improve cognitive control (Anguera et al., 2013).

As a result, the current research, which is also primarily concerned with the connection

between technology and self-regulation and using interactive technologies to impact self-regulation of desires and behaviour, therefore exists in the overlap between the fields of human-computer interaction and psychology. This research is also tangentially related to research in health and food science, although I do not heavily focus on that literature beyond their application in the field of human-computer interaction and psychology. Therefore, I maintain a psychological science and human-computer interaction approach to studying the aforementioned problems and research questions (See Figure 1).

Method

This research uses quantitative analysis to test derived hypotheses and to explore research questions for preliminary analysis, and qualitative analysis to develop a richer understanding of the underlying psychological mechanisms and to identify future research hypotheses. This research also provides critical analysis of existing research to provide insights on how we can better understand self-regulation and effectively design technologies to improve it. I also use an iterative process of designing and implementing prototypes that are designed and developed for studying self-control and self-regulation improvement.

To investigate the relationship between the new phenomenon of the Freemium design model, I used mixed methods to investigate the relationship between self-regulation and in-app purchases in a free-to-play game (study 1). The survey study provides quantitative and qualitative analysis and a discussion of this relationship.

To investigate my research questions regarding self-control improvement, I created a few prototypes that allow for targeting cognitive-control processes, and later I tested the prototypes in an experimental study that quantitively analyzed players' self-control performance and quality of experience when playing the self-control game (study 2).

To investigate my research questions regarding improving self-regulation of desire and behaviour, I used a variety of methods. I have designed an online experimental study to conduct a quantitative test to explore the impact of temporal distance and abstraction level of photos by using a simple framing technique (study 3). I also conducted a lab experiment to investigate using media technologies by using framing and saturation techniques (to impact the psychological distance and level of abstraction) to mediate people's perception of tempting foods to reduce the level of temptation and experience of strong desires toward such foods, and then provided design recommendations drawn from the findings (study 4). I then

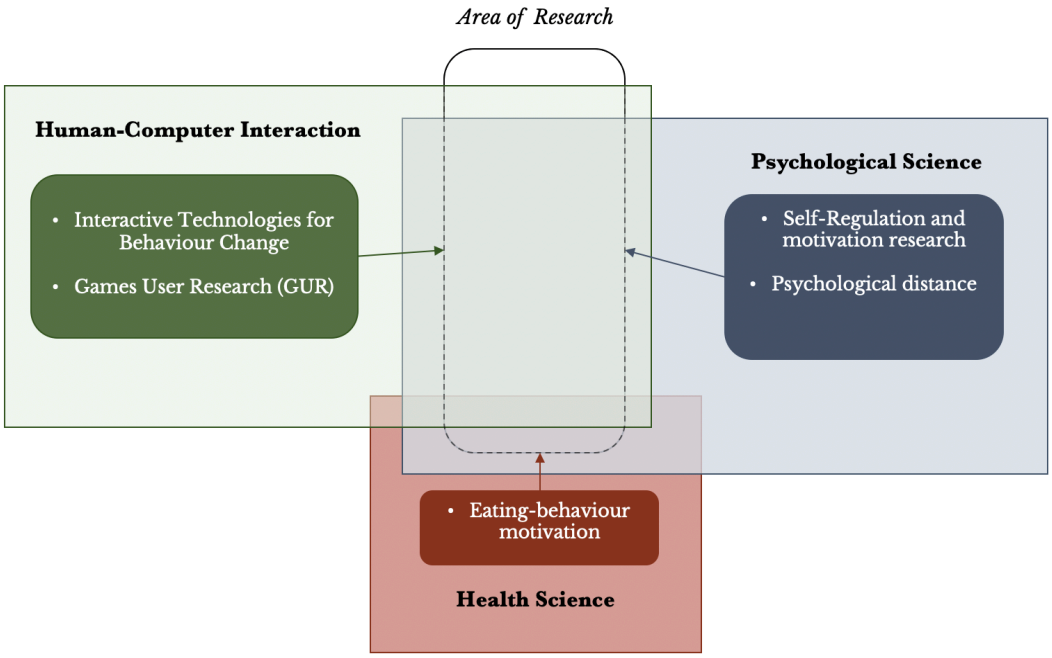


Figure 1. The scope of research in the dissertation.

designed prototypes to investigate the design of such interaction techniques in simple media technologies (i.e., mobile phones). Lastly, I conducted a preliminary study (study 5) based on the mobile application by using a longitudinal experimental design to investigates the effectiveness of the design on people's experience of temptations and unwanted desire and success in pursuing their eating-behaviour goals.

Contributions

Broadly defined, the contributions of this research provide required knowledge regarding how we can design interactive technologies to promote self-regulation and improve people's self-regulation competency. I also consider the associated challenges that arise when designing such technologies, and explore shortcomings of the current state of research to revise our theoretical understanding of self-regulation and self-regulation improvement, especially when using interactive technologies to achieve it. More specifically, the contributions of this thesis are as follow:

- Empirical evidence regarding the relationship between self-regulation and the relatively new phenomenon of Freemium design models (Study 1) that revealed a connection between individuals' trait self-control and purchasing decisions. It also provides additional insights and observations regarding people's experience of self-regulation conflict and possible motivational and emotional struggles when using Freemium games.
- Design of a self-control game (Save the Garden) that targets various self-control functions and allows for empirical evaluation.
- Empirical study regarding using self-control games to target and improve self-control by considering players' experience and engagement (Study 2) that showed some preliminary findings regarding using self-games for challenging and improving

mechanisms and practicing self-control.

- A commentary on the controversies related to the ego-depletion model, which provides a high-level perspective regarding the current state of research and issues to study and design for cognitive control and self-control improvement.
- A critical review of research about the concept of psychological distance, which highlights its significance as a central factor to consider when designing for improving the self-regulation of desire and behaviour.
- Empirical evidence on using a simple design technique to impact people's perception of temporal distance and level of abstraction (Study 3) that revealed only a slight change in perceived temporal distance and no difference in level of abstraction. These findings were also notably contradictory to what is presented by construal-level theory on the relationship between abstraction and psychological distance.
- Empirical evidence regarding testing interaction techniques to battle temptation of visually desirable food items through simple image filters that could be used with commonly accessible technologies and integrated with more advanced technologies (Study 4). The evidence shows the effectiveness of saturation techniques in helping people experience less temptation and unwanted desires by visually mediating what they experienced. These techniques inform researchers of simple technological interventions that help people distance tempting food objects.
- Design of a mobile application (Foodie Willpower) that incorporates the findings of Study 4 in addition to design elements that were inspired by our self-regulation knowledge that allows researchers to test these interaction techniques in a design prototype that could be used longitudinally in an intervention similar to a commercial product.
- Empirical evidence regarding testing the mobile application in a longitudinal study to impact people's experience of unwanted desires and temptations. Participants'

success in achieving their eating-behaviour goals (Study 5) provides preliminary evidence demonstrating the effectiveness of design features and interaction techniques for regulating desire and behaviour, including some evidence regarding the features that were specifically designed to help people reduce the temptation of food items and distance them when using the app.

Overall, the research in this thesis provides various insights into the connection between interactive technologies and self-regulation processes and improvement.

Thesis Overview

A brief overview of the content of the thesis is as follows: Chapter 2 discusses the main and basic related work in psychology, specifically in self-regulation and motivation research, and human-computer interaction, specifically in the use of games and other interactive technologies for behaviour change and increasing motivation. Chapter 3 includes Study 1, which focuses on a new phenomenon of free-to-play games and examines how elements of gameful interactive designs can undermine self-regulatory processes. Chapter 4 includes a study that focuses on investigating cognitive control tasks that can be used to engage broad processes of self-control, while Chapter 5 includes a commentary that discusses controversies surrounding topics regarding theories of self-control improvement. Chapters 6-9 include a critical review of work related to psychological distance, and Studies 3-5, which focus on investigating novel and broader approaches to improve self-regulation inspired by methods to increase psychological distance and abstraction level of a tempting object or situation. Finally, chapter 10 provides recommendations for future work while discussing possible limitations of the research in this thesis.

Chapter 2
Related Work

The objective of this chapter is to provide a general literature review as a basis for understanding work that is related to the current research. Here I draw connections between research on self-control and self-regulation improvement and research on motivation and behaviour change in human-computer interaction in order to demonstrate the benefits of using interactive technologies as self-regulation interventions. Further, I identify gaps in existing research on using interactive technologies for self-regulation improvement, which the current research aims to fill. First, I provide a review of the psychological science literature on self-control, self-regulation, and cognitive control. This review includes a thorough explanation of the psychological processes that lead to successful self-regulation as well as factors that have been shown to improve self-regulation, particularly those that are applicable to interactive gameful technologies. In this review, I will also discuss various challenges to successful self-regulation and how different mental operations and cognitive strategies can be used to overcome those challenges.

Self-Control and Self-Regulation

I drew from self-regulation, self-control, and cognitive control literature in psychology to inform my approach and study designs. Because this literature may not be familiar for all readers, I review it in detail. I then draw connections between my work and the current human-computer interaction research related to self-control and self-regulation.

Defining Self-Control

In daily life, we all engage in the regulation of our thoughts, emotions, and behaviour to achieve desired states. The term self-regulation is often used more broadly to describe processes involved in goal-directed behaviour (Hofmann, Schmeichel, et al., 2012). Self-control has also been used interchangeably with self-regulation (Duckworth & Kern, 2011) , but is conceptualized as a subset of broader processes (Hofmann, Schmeichel, et al., 2012) for resolving conflicts between competing dual motivations (e.g., a goal-desire conflict) (Fujita, Trope, et al., 2006; Fujita, 2011) or for altering and overriding our own responses "to bring them into line with standards such as ideals, values, morals, and social expectations, and to support the pursuit of long-term goals" (Baumeister et al., 2007b). The issue of self-regulation failure may seem simple at first glance; however, a more in-depth understanding of psychological processes and strategies is required for understanding self-regulation, the causes of its failure, and the mechanisms for improving it. Defining self-control and self-regulation seems straightforward at first but proves to have important implications for theoretical understanding and experimental methods regarding relevant concepts.

Self-control has been commonly considered an effortful impulse control (Baumeister et al., 2007b). This definition limits our understanding of self-control processes that do not include mental operations mentioned previously and various less effortful strategies in a self-control dilemma (Fujita, 2011). Therefore, defining self-control as effortful impulse inhibition consequently reduces our understanding of a self-control situation to momentary acts of impulse control which does not inform researchers regarding the involved *processes* and therefore the overall *experience* that the person has in the self-control conflict situation. For Instance, when playing freemium games, a player with a limited budget or with a preference to spend less money might face the need throughout gameplay to resolve possible conflicts between the motivation to spend less money and the motivation to keep playing or winning the game. Considering the same situation as an example of failure or success in resisting impulses, however, does not provide any insights into people's experience. Importantly,

considering such instances as examples of goal conflict opens the door to interventions that help people to resolve competing or conflicting motivations by maintaining desired *psychological distance* toward our goals.

In this thesis, self-control is conceptualized instead as managing or resolving competing or conflicting motivations, which could be exercised with or without significant effortful processes for controlling and overriding interfering impulses. This definition also helps us better understand the totality of a self-control situation and, therefore, understand how it relates to the research questions and problems examined in this and the following chapters. Notably, self-regulation does not always involve effortful impulse control, but can involve various techniques to help people experience *less* temptation or effectively distance themselves from desirable objects, resulting in less need for impulse control.

Cognitive Control

A broader level of top-down cognitive processes, known as executive functions (EFs) for cognitive control, arguably is related to the general capacity for self-regulatory functions (for a review, see Hofmann, Schmeichel, et al., 2012). These self-regulatory abilities enable individuals to govern the self and pursue goal-directed purposes more generally (Diamond, 2013). The collection of these functions can be organized into three main categories: *working memory*, the holding, using, and updating of relevant information to our goals; *inhibitory control* on responses over automatic and prepotent processes; and *task switching*, the mental flexibility to adapt to new circumstances and shift among a set of cognitive tasks to manage goals (Diamond, 2013; Hofmann, Schmeichel, et al., 2012). These processes play an important role in the capacity for self-regulation of behaviour (Duckworth & Kern, 2011; Hofmann, Schmeichel, et al., 2012), with some evidence that links them to physical and mental well-being and successfully self-regulating outcomes such as academic and job achievements,

addictions, and criminal and violent behaviour (for a review, see: Diamond, 2013). However, a direct link between the basic executive function of impulse control and self-regulation of behaviour on a trait-level has been questioned (e.g., see: Saunders et al., 2018) and requires further research to better understand exactly how these functions contribute to broader cognitive-affective and behavioural aspects of self-regulation.

Broader Self-control Processes

A person who wishes to improve his or her capacity for self-regulation more broadly, encompassing all the aforementioned self-regulatory functions, would still draw from more general self-regulatory mental operations and strategies (Duckworth et al., 2016; Fishbach & Converse, 2010; Myrseth & Fishbach, 2009a). For example, in a self-control conflict, people need to evaluate choices and choose to resist an instant or short-term gratification of pursuing desires and tempting rewards or goals for a delayed reward, as in the Marshmallow Test (Mischel et al., 1989). It is important to first note that the procedures of self-control delay tasks such as the Marshmallow Test are different than those in self-control executive function tasks that require cognitive control. However, it relies on cognitive control and shares essential features (Casey et al., 2011; Eigsti et al., 2006). For example, averting attention from tempting marshmallows and cookies involves inhibiting and overriding automatic and prepotent responses to control behaviours and thoughts (Eigsti et al., 2006) and also involves the proper operation of working memory when encountering temptations (Hofmann et al., 2011). These fundamental features indicate a *general* link between successful self-regulation of behaviour and cognitive control [20,39].

In contrast to these broad 'cool' cognitive processes, we can talk about different self-regulatory functions and operations that support pursuing goal-directed behaviour. One example of such cognitive functions that enables us to regulate desires is delay of gratification

(Metcalfe & Mischel, 1999; Mischel et al., 1972b; Mischel et al., 1989), which refers to evaluating choices, and choosing to resist an instant or short-term gratification of pursuing desires and tempting rewards or goals for a delayed reward, as in the Marshmallow Test (Mischel et al., 1989). Also, the distinction between more specific self-regulatory functions and more general higher-level processes corresponds with different kinds of operations and self-regulatory strategies (Duckworth et al., 2016; Myrseth & Fishbach, 2009a). A person who wishes to improve the capacity for self-regulation more broadly, encompassing all self-regulatory functions, would draw from more general self-regulatory strategies (Duckworth et al., 2016; Fishbach & Converse, 2010; Myrseth & Fishbach, 2009a). Such strategies include learning more generally to modify one's focus of attention and re-evaluate a given situation (e.g., adopting a more abstract view of the situation to re-evaluate choices in the near and distant future), or selecting or modifying situations to facilitate successful self-regulation (Duckworth et al., 2016), such as actively choosing situations that impose minimum temptation or distraction that interfere with our goals. A person who develops skills to be able to actively choose situations that will allow them to effectively self-regulate should be equally effective at a wide range of specific self-regulatory tasks, for example, effectively delaying gratification by avoiding the dessert tray, or being able to switch tasks more effectively by finding a quiet place to concentrate.

Therefore, a more in-depth look into such self-regulation strategies and their related mental operations allows us to better understand why we need to target broader self-control competencies to help delay gratification.

Challenges in Delaying Gratification

In this thesis, I will use *delay of gratification* as a construct that is defined as a choice dilemma between less valuable immediate versus more valuable distant outcomes; this choice dilemma results in a self-control conflict (Hoch & Loewenstein, 1991; Loewenstein, 1996;

Mischel et al., 1989).. Therefore, a broad range of self-control dilemmas involve a conflict between choices related to short-term desires and long-term goals, resulting in conflicting motivations.

An essential challenge to successful self-regulation then is *transcending* the immediate stimuli or outcomes of the situation and considering more temporally distant outcomes or a more abstract view of the situation (Baumeister et al., 1994; Baumeister & Heatherton, 1996). There are cognitive operations that can help us transcend the immediate situation and regulate our behaviour by modulating our mental representation of a situation, which changes how we make meaning out of a situation (Fishbach & Converse, 2010). For instance, a dieter can construe a tempting object in different levels of abstraction. They can, for example, think of a cookie as either a tasty and pleasurable snack, or as a food selection in a series of choices related to a dieting plan he or she set for the month.

We can identify two major challenges in transcending an immediate situation, which correspond to the self-regulation strategies that we can use. First, it is typically challenging to think about the distant future and its outcomes, which could help us think beyond the immediate situations. This results in a phenomenon that is generally classified as the *temporal discounting* of future outcomes based on their psychological distance , such as the temporal distance of an event that happens in a year (e.g., thinking about the positive outcomes of performing well on a test).

Our minds possess the fascinating ability to travel through time to imagine future events as if we are living them and experiencing their details; however, when we are making a decision, it is a considerably effortful process to take into account events in the distant future. We tend to think more about easy-to-imagine outcomes when elaborating on close-futures versus distant-futures in relation to outcomes of our decisions and behaviour (Nenkov et al., 2008). Future self-similarity is also another important factor impacts how we value the

desirability of outcomes for the self in the future and our ability to delay gratification in favor of the future self (Ersner-Hershfield et al., 2009). Also, the vividness of our future self (van Gelder et al., 2013), that is, feeling it as more psychologically close and connected to the self, can influence our mental operations when thinking about our choices and their future outcomes, which greatly affects our ability to self-regulate our behaviour in favour of our long-term goals and desirable outcomes.

Second, another challenging factor in transcending the immediate situation is the ability to change the construal level of mental processes, known as the level of *abstraction*. We can construe an event or an object either by abstract mental representations (relating to its superordinate, central, goal-relevant features) or by concrete representations (relating to its subordinate, incidental, goal-irrelevant features) (Trope & Liberman, 2003; Trope & Liberman, 2010). Accordingly, we use high-level, more abstract construals of an event or an object, which are goal-related and less incidental, to think beyond an immediate situation that we experience in the moment. In other words, a high-level construal more easily "traverses psychological distance" (Trope & Liberman, 2010), such as when we want to think about future or past events.

Therefore, to think beyond the immediate consequences of an outcome and transcend the immediate situation we need to shift our mental processes to a more abstract level. A self-control dilemma can be analyzed similarly, as it involves competing motivations between more local (proximal) incentives and more global (distant) concerns (Fujita et al., 2006; Fujita, 2008) especially when it involves hedonic experiences. Therefore, having or shifting to a high-level construal of an event will facilitate taking into account global abstract (goal-relevant) outcomes (Fujita, 2008). For example, a dieter who places more weight on choices that help them keep a healthy diet and be physically fit is thinking more globally.

This distinction translates into the difference between global (gestalt) and local visual

perceptions of a situation (Förster, 2012; Förster & Dannenberg, 2010). One example is when people use local processing to attend to the content of a marshmallow (features relating to its consumption) rather than attending to a more global set of stimuli in the situation (more abstract context) (Förster & Dannenberg, 2010; Mischel et al., 1989). Hence, a major challenge regarding tempting objects or options that narrow our attention is changing how we attend to and think about the situation. This mental operation facilitates a modulation of the meaning of the situation to better transcend the immediate situation in self-control dilemmas (Fishbach & Converse, 2010; Myrseth & Fishbach, 2009b).

Altogether, this literature on self-regulation suggests that it is important for interventions to focus on improving broader self-control capacities to successfully impact the self-regulation of behaviour. I will argue later that this goal can be achieved through interactive designs that facilitate practicing broader self-regulation strategies than are traditionally targeted in self-control interventions. An effective intervention would need to overcome major interrelated challenges to transcend immediate situations and successfully self-regulate our behaviour. However, the visual and metaphorical nature of these challenges makes interactive technologies a particularly useful tool that could allow individuals to practice these mental operations and related self-regulation strategies.

Interactive Technologies and Self-Regulation Improvement

Games Research and Behaviour Change

Videogames are highly interactive media that can create long-term engagement and provide rich psychological experiences (Przybylski et al., 2010; Ryan et al., 2006). For these reasons, researchers have attempted to harness the power of videogames for a variety of purposes in altering human behaviour. Such attempts use game mechanics to encourage specific

behaviours. For example, Foldit (Cooper et al., 2010) is a game that encourages problem solving through crowdsourcing, encouraging players to invest significant effort at folding protein structures in the name of science. Systems have also been designed that use game elements, such as points, levels, and avatars to motivate behaviour. For example, HabitRPG (now referred to as Habitica) is a gamified system to improve productivity in managing tasks, habit, and other daily activities, and SuperBetter (McGonigal, 2015) is designed to help people strengthen habits, tackle various personal or social life goals and challenges, and assist others.

To encourage such behaviours, researchers also have focused on influential theories of motivation, such as *self-determination theory* (Ryan & Deci, 2000) and *flow theory* (Csikszentmihalyi & LeFevre, 1989) which stress creating autonomous contexts, promoting player experience, and finding an optimal level of challenge. Other research, more in line with the objectives of this thesis, has focused on improving *mindfulness,* which can facilitate affective well-being and self-regulation (e.g., Tang et al., 2007) through multiple mechanisms (Kang et al., 2012; Shapiro et al., 2006). An example of this research in human-computer interaction research is *PsychicVR*, a design that uses brain-computer interfaces and virtual reality to provide real-time feedback, thus increasing mindfulness while creating a playful experience (Amores et al., 2016).

Interactive Technologies for Measuring and Improving Self-Control

The work most closely related to the current research has focused on improving self-control through interactive media either by testing the effects of existing commercial games or designing new games to improve self-control—that is, to improve specific cognitive control processes.

There are various categories of commercial games designed to improve numerous specific

cognitive abilities, including cognitive control. On one hand, there are commercial games, known as "Brain Games," such as Big Brain Academy: Degree Wii, or games by Lumosity, promoted as a means of improving one's cognitive abilities. These games' appearance and media campaigns may lead people to think that they can improve one's cognitive abilities. However, a group of cognitive scientists recently issued a statement that there is little evidence to conclude "Brain Games" are effective and that they need further and broader investigation (see: Max Plank Institute Report, 2014). The same issue has led to a lawsuit against Lumosity creators and marketers (FTC Report, 2016). Researchers have also attempted to improve attention and working memory by using action video games (e.g., *Medal of Honor*). While some studies have found no evidence to support the effectiveness of such games for the general public, others have found them to be effective for specific groups of people with impairments in cognitive control (for a review, see: Anguera & Gazzaley, 2015). On the other hand, *Neuroracer* is a game designed for the purpose of improving cognitive control through multitasking and has been shown to improve specific aspects of cognitive control in older adults (Anguera et al., 2013). Prins et al. (2011) also showed promising improvement in working memory in children with ADHD when using game elements to improve intrinsic motivation and self-efficacy (also, see: Anguera & Gazzaley, 2015).

Improving Self-Control Capacity or Executive Functions

A number of studies that have attempted to investigate improvement in self-control processes have been based on the assumption that regularly practicing a simple task that requires self-control will improve overall self-control capacity (e.g., practicing a handgrip task or using one's non-dominant hand for daily activities over the course of a few weeks; for a review, see: Friese et al., 2016; Inzlicht & Berkman, 2015). This idea is based on the *resource model* of self-control (Baumeister et al., 2007a) which conceptualizes that self-control relies on a limited pool of a resource and practicing self-control will increase this limited resource. However, these promising aspects of the resource model have recently been called into question

by meta-analyses (Carter et al., 2015; Carter & Mccullough, 2014) and failures to replicate existing studies that initially provided evidence for its theoretical basis (Friese et al., 2016; Hagger et al., 2014; Inzlicht & Berkman, 2015; Miles et al., 2016) that includes a first and second replication failure by main advocates of the model (Vohs, K. D. et al., 2020). Thus, some research highlights the need for changing the approach of simply repeating a single task as an effective way to improve self-regulation capacity (Miles et al., 2016). Similarly, researchers have failed to find sufficient evidence that practicing working memory necessarily improves a person's *overall* capacity for cognitive control (Melby-Lervag et al., 2016; Melby-Lervåg & Hulme, 2013). Executive functions are essential mechanisms for successful self-regulation, but a person who is specifically concerned with improving working memory might implement strategies that are not likely to generalize to other self-regulatory capacities. Consequently, people may see an improvement in working memory, but not in their ability to delay gratification and resist eating a desirable treat.

Altogether, this research leads us to the following conclusions: First, a game that effectively improves self-control will need to present proper challenges for a given player to ensure that their cognitive capacities and skills are being challenged and improved without decreasing engagement. Similarly, such a game would need to promote intrinsic motivation and self-efficacy. Further, such a game cannot rely simply on repeating a simple task over and over if it is intended to improve a broad range of self-control capacities.

Notably, all of these points converge on a similar recommendation that we need to take into account an individual's capacity for cognitive control and various aspects of the quality of their experience when designing a game for improving self-control capacity, which informs my second study investigating self-control games designed to target individuals' capacity for self-control while examining their quality of experience.

Designing Interactive Technologies for Improving Self-Regulation

Some interventions designed to improve self-regulation of behaviour attempt to improve the delay of gratification directly. As mentioned before, relevant examples of improving self-regulation that involve learning strategies, such as modulating construal-level and related attentional systems, are based on original studies of delay of gratification in children by Mischel et al. (1972b; 1989).. They demonstrate the possibility of learning indirect instructions to improve abstraction, such as imagining marshmallows or candies as pictures by thinking about them in an imaginary mental frame (Mischel et al., 1972b; Moore et al., 1976). These notably simple instructions increased the level of abstraction in thoughts and helped children more effectively self-regulate their behaviour and choose a delayed but valuable outcome, at least in the moment. Some of the other methods, however, seem to be maladaptive strategies if used over a long period of time because they involve altering the reality of the environment, for example, thinking about marshmallows as cotton balls or clouds (Mischel et al., 1972a; Mischel et al., 2011), which could work as effective short-term coping strategies. Despite this criticism, these techniques suggest the possibility of learning self-regulatory strategies to improve cognitive competencies for effective delay of gratification even in the early years of life. More recently, other researchers have investigated the importance of abstraction on transcending temptations (Fujita & Carnevale, 2012), and its fundamental role in self-regulation mechanisms (Fishbach & Converse, 2010; Fujita & Carnevale, 2012; Fujita, 2011).

There are various components of the self-regulation of behaviour that researchers focus on to successfully create intervention techniques, including improving how people are setting goals, implementing them and monitoring progress and discrepancies between the current and desired state (Fishbach & Converse, 2010; Inzlicht et al., 2014; Myrseth & Fishbach, 2009b). It is important to mention that since many of these components are intertwined

(Baumeister et al., 1994; Inzlicht et al., 2014), digital help tools often incorporate more than one in their design.

Setting meaningful and difficult yet achievable goals is an important factor in goal pursuit (Inzlicht et al., 2014; Locke & Latham, 2002). Many researchers have studied using technology in assisting people with different aspects of planning their goals. Task-planning, fitness, or diet mobile apps are well-known examples of these approaches that help us make daily or weekly plans to achieve our goals. Although these techniques could be effective in the short term, it remains challenging to achieve long-term effects (Pinder et al., 2018), or to deal with more complex and difficult goals such as weight loss (Mann et al., 2007). For example, studies have shown that dieters using different weight-loss programs or apps could re-gain lost weight or even gain more in the long run (Mann et al., 2007).

In addition, resisting temptations that interfere with these goals is another obstacle that makes it less likely for people to delay gratification and stay committed to their values and standards by implementing their goals (Mischel, 1974; Mischel et al., 1989), especially when we factor in the hedonic experience of dealing with tempting situations. Researchers have highlighted the importance of taking these affective components into account (Hofmann & Van Dillen, 2012; Kavanagh et al., 2005) as often strong desires that interfere with our goals or standards can become temptations, and therefore substantially hinder our ability to control behaviour (Hofmann, Adriaanse, et al., 2014; Hofmann, Baumeister, et al., 2012). Strong desires can emerge quite automatically by mental images or environmental stimuli, impact our working memory, and motivate our impulsive and habitual responses. As a result, they ultimately have a significant effect on our cognitive processes, hinder self-control efforts, and possibly interfere with the pursuit of other goals as well.

When a person is skilled in goal-setting and planning, behaving in concordance with our intentions and making changes to our behaviour still proves challenging, given the difficulty

of resisting temptations and staying motivated to keep pursuing one or multiple goals (Hofmann, Baumeister, et al., 2012; Inzlicht et al., 2014).

Researchers in HCI have rightly paid a great deal of attention to motivational factors of goal-pursuit, for example, by using game elements to increase the quality and strength of motivation (Deterding, 2011; Deterding & Dixon, 2011). For example, studies have used gamification techniques to help people improve their performance in various tasks or daily life goals such as changing health-related habits (McGonigal, 2009). Others have also explored commitment techniques by using technology to allow people to create self-imposed restrictions (Rogers et al., 2014), for example, by limiting access to certain websites or access to the Internet, designing an app limiting the time allowed to spend on other mobile apps (Löchtefeld et al., 2013), or using payment systems to self-impose penalties for not adhering to pre-determined goals (Ashraf et al., 2006).

On the other hand, many studies in HCI have focused on investigating designs for tracking goal-progress and monitoring different aspects of related daily activities that might promote or hinder goal pursuit. For instance, studies have explored the design of apps to track the time spent on various apps (Kuznetsov & Paulos, 2010; Heyoung Lee et al., 2014), gamified feedback systems have been used to monitor progress and use motivating elements such as points and levels (Deterding, 2012; Deterding et al., 2011; Deterding & Dixon, 2011), and new technologies have been designed, such as wearables to help people more easily track or self-monitor their emotions, thoughts, or actions (Case et al., 2015).

However, there is a notable lack of focus on mitigating the unwanted desires people experience frequently every day. Recent advances in technologies such as smartphones, smart-glasses and virtual-reality headsets might allow us to mediate how people visually perceive the environment. My work builds on this past work by investigating a simple technological intervention of using a mobile device to address strong desire and temptation by distancing

oneself from the temptation in the moment with image filters or even the simple frame of the phone.

In summary, when designing technologies to help improve self-regulation, we need to consider broader aspects and challenges of that result in self-regulation success or failure such as the hedonic experiences that exist in a self-control conflict and complexity of self-regulation challenges that may require new and broader approaches to self-regulation improvement.

Chapter 3
Interactive Gameful Technologies and Self-Regulation Failure

Gameful and interactive designs could provide great benefits in motivating people to pursue their long-term goals more easily and effectively. However, the same design elements could also be used to motivate people to spend more money on platforms by capitalizing on the very same psychological processes. In this chapter, I explore the new phenomenon of free-to-play games and the relationship between the amount of money and time users spend and their self-regulation capacity.

We need to investigate the positive or negative impact this new phenomenon may have on people's self-regulation. In order to provide a good understanding of how these design elements can affect self-regulation success or failure, I conducted a correlational study to explore this phenomenon empirically and provide insights into how engaging with free-to-play games can impact players' experience and decision making by influencing their motivational and self-regulatory processes.

Study 1: Self-Regulation and In-App Purchasing Decisions

An individual's self-regulation competency plays a major role in managing one's desires and mobilizing behaviour change in all contexts, including game playing. In this study, I examined whether there is a self-control dilemma to players' behaviour and decision-making in Freemium games, specifically Candy Crush Saga™. I present the results of an online survey that examined a variety of psychological factors that may impact players' behaviour in casual games that make use of in-app purchases, including self-regulation, game addiction, problem video game playing, as well as documenting players' described experiences of what it is

like to purchase game power-ups.

In this study, I investigated the degree to which a person's capacity for self-regulation (i.e., measured by trait self-control) is related to the amount of money they spent in Candy Crush Saga™. I will also describe a more detailed analysis of Freemium players' experiences to determine if participants experience self-regulation conflicts when playing the game and if they negatively experience any tensions as its result.

Freemium Games and In-App Purchases

New forms of business models such as Freemium and micro-transactions are commonly used, especially in mobile video games. Freemium business models provide users with a free of charge product, but they charge for various additional purchases. The word is a combination of *free* and *premium* to represent both meanings in the business model. Freemium models usually combine with micro-transaction in-app purchases (IAPs). The amount of IAPs in casual games is an interesting phenomenon to carefully investigate. Freemium companies design additional features and services that players can purchase, enjoy, and explore in the game. The increasing use of this business model, especially in videogames, highlights the importance of investigating its influence on players in terms of understanding the process of decision-making, their interaction with the applications, and their feelings when playing (e.g., Chen, 2012; Raney, 2013). Among Freemium games, Candy Crush has enjoyed rapid success and the amount of money paid through IAPs is extraordinary. The amount of money spent on the game, in addition to players' stories in the news regarding how they spend time and money (Brockes, 2014; Demos, 2014; Wingfield & De La Merced, 2014) lead to research questions about player's decision making about the amount of money they spend or the amount of time they spend playing the game.

Game designs that hinder control in the face of temptations.

Current Freemium games are designed to influence players in various ways. In this section, I discuss how current Freemium game designs could work as a low-cost temptation by explaining the mechanism of self-regulation and how current designs of in-app purchases in games might undermine players' experiences at the individual, group, and societal levels.

Low-Cost Temptations

Individuals need to exercise self-regulation when they face a self-control conflict. People must first identify the conflict between temptations and their long-term goals and then implement goal-directed behaviours. These stages can also work as iterative and interrelated processes (Inzlicht et al., 2014). It is important to emphasize that only after identifying a self-control conflict would people be able to implement self-regulation strategies to achieve their goals. Therefore, identifying stages of the self-regulation process works as an input for the next stage. When one does not successfully identify the choice conflict to monitor behaviours, they do not exercise self-control (Myrseth & Fishbach, 2009b).

However, current Freemium game designs, which rely on various types of micro-transactions (accompanied by various choice architecture methods to motivate people to make a purchase), create relatively low-cost temptations at each point of purchase. Temptations with lower costs make it more difficult for individuals to identify the choice conflict between the immediate temptation and one's long-term goals (see e.g., see: Fishbach & Converse, 2010; Myrseth & Fishbach, 2009). For example, if a person has a large, long-term savings goal, spending $1 in order to avert the frustrations of being stuck on a level in the game may seem negligible as a *single* purchase decision. However, repeated ongoing neglect of such low-cost temptations over time can be significantly costly for the success of an individual's long-term goals. Such decisions are comparable to a dieter who thinks "just one" donut is fine, and then proceeds to choose to have "just one" donut repeatedly without attending to the conflict

throughout the day until the consumption rate becomes salient. These situations make it more difficult for people to monitor their purchasing behaviour and the behaviours consistent with their long-term goals in a *single* purchasing decision.

Game Design Patterns

Some work describes the different design patterns that have been used in Freemium or Free-to-Play (F2P) games, which encourage people to engage more and spend more money in the games. Zagal et al. (2013) describe several patterns that have been frequently used and could be considered questionable, or even unethical. Lewis (2014) also identifies three "dark" design patterns and how to avoid them: *currency confusion*, *pay to skip*, and *monetized rivalries*. Other studies focus on the social aspect of business models for social games, and indicate various reasons that people engage and purchase virtual goods in social network games.

Therefore, when considering the effect of various design patterns, such as "dark design patterns", or incorporating low-cost temptations in new design models, we should think about how these designs can directly or indirectly impact people's motivational system and decision making when they regularly use them.

While some related work discussed design patterns for games as well as both the "dark" side for players and the business opportunities for designers, they have not shown a direct empirical connection between self-regulation and purchasing decisions. In this work, I specifically investigate this connection.

Method

I conducted a study to investigate the relationship between a person's self-regulation competency and their spending behavior in Candy Crush Saga™. I conducted an online crowdsourced survey in order to explore the associations between participants' self-reported trait

self-control and the amount of money they tend to spend in Candy Crush Saga™. Previous research shows a relationship between trait self-control and addiction in videogame players (Mehroof & Griffiths, 2010). Therefore, I also included a game addiction scale and a problem video game playing scale to investigate if any associations I found persisted even when controlling for game addiction and problem video game playing. I also asked participants about the average time and duration of actively playing Candy Crush Saga™ to test how the time they spent in the game influenced other factors.

Participants

I recruited 88 American participants (54 identifying as female, 34 identifying as male) through Amazon Mechanical Turk (MTurk). I specifically advertised this research on MTurk as a study that needs participants who were (at the time) actively playing Candy Crush Saga, in order to be able to ask about their recent experience in gameplay.

Procedure

The survey included several validated scales and questions regarding players' experiences while playing the game. They were first asked to complete the Self-Control Scale (Tangney et al., 2004a) that measures a broad range of self-regulation competencies and successful use of self-regulation strategies, and then asked about their overall experience playing Candy Crush Saga™ with respect to the amount of money they spent, the amount of time they played, and their general behaviour and feelings when playing. Next, they were instructed to imagine their experience specifically over the past week when playing Candy Crush Saga™ and respond to the Game Addiction Scale (Lemmens et al., 2009) and the Problem Videogame Playing Scale (Salguero & Morán, 2002). Finally, they were asked to describe in free-form text their typical experience of deciding whether or not to spend money in the game.

In addition to the validated scales, I also asked questions regarding the amount of money participants spent when playing Candy Crush Saga™, about the different ways that they spent money (e.g., buying more "moves" when they are out of moves and stuck in a level, or boosters that helps them *smash* candies and progress when they need to, which were the types of in-app purchases a player could make using the currency in the game), and whether they considered the amount they had spent to be a lot. I also asked participants to report the average amount of time they spent daily in the game, the number of months they had been playing the game, and to rate their level of experience on scale of 1 to 10. To conclude the study, I asked participants to think of a moment in the game when they decided whether or not to spend money. I asked them to report on this experience, including a description of their thoughts, feelings, and different reasons that may have influenced their decision.

Hypotheses

I first wanted to explore if self-regulation failure might have an effect on how much a player spends money in the game. It is also important to investigate if the amount time someone plays the game has any effect on these decisions or, for example, if there are other factors such as game addiction that could play a role on these decisions, as it was shown before that there might be connection between game addiction and trait self-control in general.

I specifically identified the following hypotheses:

H1: Participants with a higher level of trait self-control spend less money on in-app purchases.

H2: Participants who spend more money on in-app purchases spend more time playing the game.

H3: Participants with a lower level of trait self-control have a higher level of addiction to the game.

Results

Of the 88 participants, 30 reported ever spending money in the game. Therefore, about 66% of the participants did not spend any money. This finding regarding the sample population is consistent with a report from Candy Crush Saga™ developers, King's Company, which found that 70% of players on the last level have not spent money in the game (Dredge, 2013).

Correlations

Results of Pearson correlation analysis for some of the main variables in our study are presented in Table 1. No data were excluded from the analyses. There was a significant negative correlation ($N = 30$, $r = -.400$, $p = .029$) between the amount of money participants spent and trait self-control, providing evidence for H1. Figure 1 shows the relationship between money spent in dollars and trait self-control, with the area of each circle representing time spent in the game.

Table 1.

Relationship between variables: Pearson Correlation Coefficients

Scales	Variables					
	Amount of money spent in the game (N=30†)	**Trait self-control (N=88)**	**Average playing time (N=88)**	**Duration of playing (N=88)**	**GAS (N=88)**	**PVP (N=88)**
Trait self-control	**-.400* (.029)**	–	-.083 (.441)	-.056 (.605)	-.195 (.069)	-.071 (.514)
Average playing time	.124 (.515)	–	–	.161 (.134)	**.318** (.003)**	**.279** (.009)**
Duration of playing	-.071 (.708)	–	–	–	-.116 (.283)	-.094 (.383)
Game addiction scale (GAS)	.123 (.518)	–	–	–	–	**.700** (<.001)**
Problem video-game playing (PVP)	.202 (.284)	–	–	–	–	–

Parentheses show standard errors in the analysis. *p<.05, **p<.01,
† Only 30 of 88 participants reported spending any money, so the other 58 were excluded from the analyses presented in this column.

There was also a significant relationship between the average time spent and both GAS (N = 88, r = .318, p = .003) and PVP (N = 88, r = .279, p = .009). However, the average GAS score was 46 of 105 and the average PVP score was .26 out of 1.0, which are not considered high. The amount of time spent in the game was neither significantly correlated with the amount of money spent in the game (N = 30, r = .124, p = .515), nor with their trait self-control (N = 88, r = -.083, p = .441). Hence, these results do not confirm H2. Trait self-control had a correlation with the level of game addiction (N = 88, r = -.195, p = .069) though did not reach significance level, which provides partial evidence for H3, and not significantly correlated with problem gaming (N = 88, r = -.071, p = .514).

Moreover, there is a significant relationship between the amount of money that participants

spent and their trait self-control when all 88 participants are included (N = 88, r = -.224 p = .023). However, there is a possibility of a fundamental shift in behaviour once a participant decided to spend versus not spend, for example, conversion to paying users in the game or Freemium games in general. Therefore, I did not include the rest of the participants when I analyzed the relationship between the amount of money spent in the game and trait self-control.

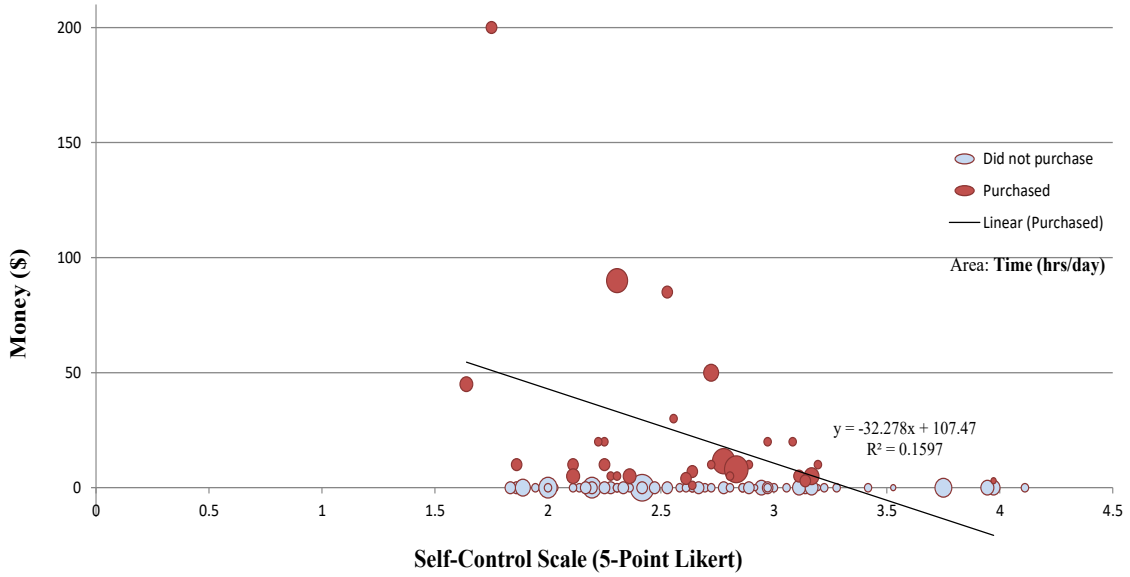


Figure 2. The amount of money spent vs. trait self-control levels and the average amount of time spent in the game for participants that spent money in the game *(N=30, area= time in hours per day)*.

Thematic Analysis of Text Responses

Participants provided free-form text responses about a moment in which they could spend money, including their responses about experiencing choice conflict in those situations, their attitudes regarding making in-app purchases to progress in the game, and their responses to questions about the factors that affect their motivations of spending money to progress in the game, coded by the experimenter. I have generated the main themes through

stages of open coding of responses provided by participants (Kolb, 2012), and discussed the categories generated through the process. I was the only coder who did the thematic analysis. I first familiarized myself with the responses through reading all the open-ended responses. I then went through the responses looking for contents that are related to their experience, motivation, decision making, self-regulation success or failure (i.e., as the open-ended question asked about their thoughts and experience when making the decisions), and finally other related factors that they might have pointed out. I then went through two rounds of iterative coding and as the result generated themes related to their self-regulation processes and strategies (e.g., self-regulation conflict), and themes related to their motivational and experiential factors that might have influenced their decisions. The following results are preliminary findings of the qualitative analysis, with the purpose of providing meaningful insights through emergent themes that can inform future hypotheses for researchers. These analyses often require an in-depth coding procedure rather than a purely deductive approach in coding that sometimes is used by researchers for hypothesis testing.

Table 2.

Participants Responses About Experiencing the Choice Conflict During the Gameplay

Label		**# Participants**	%
Experiencing Choice Conflict		33	37%
Experiencing no choice conflict	a) Having a pre-commitment, or policy to not spend any money.	22	25%
	b) Others	10	11%
Did not report		24	27%

Table 2 presents the result of the thematic analysis from participants' responses regarding related self-regulation conflict and strategies, including the participants who did not spend any money in the game, regarding detecting and resolving conflicting choices. Results shown in Table 2 indicate that 37% of the participants, including those who did not spend any money

in the game, reported experiencing a salient psychological conflict and needed to resist the desire to spend money in the game. Also, 25% of the participants who did not experience a salient choice conflict had various types of pre-commitments not to spend money in these situations (i.e., free-to-play games, or in Candy Crush, etc.), such as strong beliefs or pre-commitment about spending money in free-to-play games, et cetera. Even though these forms of commitment placed limits on their choices in the game, some participants indicated a strong premeditated self-regulation strategy to ensure future behaviour would be more consistent with their long-term goals. This pre-commitment allowed participants to resist temptation when prompted to spend money in the game. On the other hand, 11% of the participants did not experience any choice conflict, since they did not even think of spending money to progress in the game as a realistic option for various reasons, such as a limited budget.

Table 3.
Participant Responses About Factors That Affect Their Motivations to Spend Money to Make Progress

Label	**# Participants**	%
Skipping the frustration of being stuck in the game	11	13%
Being able to enjoy playing more of the game	3	3%
Skipping the experience of one or repeated failures at the verge of winning	3	3%
Did not report	71	81%

Table 3 provides three categories of responses regarding the factors that affect players' motivation to spend money to progress in the game, that is the result of the thematic analysis regarding participants experience and motivations that might have affected their decisions making. Table 4 presents thematic analysis on some additional simple themes generated from the thematic analysis on participants' responses, which is about their positive or negative attitudes regarding using in-app purchases to progress in the game.

Table 4.

Participants' Attitudes Toward Having In-App-Purchases to Progress in a Game

Label	**# Participants**	%
Thinking that spending money is not a fair or proper way of progress in the game.	15	17%
Thinking that spending money is a proper or good way to progress in the game.	1	1%
Did not report	73	82%

Discussion

The study results indicate a connection between participants' self-regulation capacity and the amount of money that participants spent in Freemium games. The results show that people with lower self-regulation capacity are more likely to spend money when prompted. The results in Table 2 also suggest that people experience a considerable degree of self-control conflict when they face a purchasing decision in these kinds of games and that they perform self-regulation strategies to overcome the desire to spend money in order to progress in the game. In this section, I also discuss some additional factors that may influence players' motivation to spend more money in these sorts of games by influencing players' self-regulation processes. I also briefly discuss the possibility of eliciting negative feelings and consequences when players face purchasing decisions as a self-regulatory aid.

Enjoy more or suffer less—The results indicate a strong correlation between trait self-control and the amount of money players spent on purchases in Freemium games. Ultimately, players face the desire to move on to the next level. However, this desire may be framed in different ways. The feelings and thoughts associated with this desire may result either from wanting to enjoy more in the game by going forward to the next level, or from the frustration of not being able to pass the current level. The distinction between these motivational

qualities have been discussed in the literature as promotion or prevention motivation (Higgins, 1998; Higgins, 1997; Scholer & Higgins, 2011), that discusses two regulatory focuses that could coexist and impact a person's motivational systems. These two regulatory focuses include promotion focus that motivates behaviour through "growth and advancement" concerns and prevention focus that motivates behaviour through "security and safety" concerns (Scholer & Higgins, 2011). To clarify which of these two motivations best represents players' experience at the decision point, I looked at free-form responses.

As discussed in the previous section, I did not find a relationship between the amount or duration of time players spent in the game with their trait self-control or with the amount of money they spent in the game. The results of our qualitative analysis also show that many participants had the experience of being "stuck" in the game. Table 3 shows that 13% of those participants experienced strong feelings of frustration. There were also several responses regarding the experience of being stuck in the game "for too long" and negative feelings regarding the experience. Based on our analysis, it seems more likely that at the point of purchase, participants are motivated by the desire to *avoid* the undesirable feeling of being stuck, rather than the desire to approach the next level. A small payment ultimately allows players to skip the considerable amount of frustration associated with their experience of the game in that moment:

> *"I'm trying really hard not to spend money on games. I did it a few times after being stuck for weeks because I was frustrated but I'm trying not to do it again." (P80)*

On the other hand, the frustration of being stuck in a game can impair successful self-regulation of players' self-regulatory resources, making it more difficult for them to fight the temptation to spend money. This tendency may be particularly problematic for individuals with generally low self-regulatory capacity. Therefore, people with lower trait self-control may be less effective at exercising appropriate self-regulatory strategies at the point of purchase and be more vulnerable to spending money in such games. One participant with a

history of several purchases described developing an effective self-regulation strategy to overcome temptation to skip the frustration by switching to another game, and therefore was able to avoid spending money:

> *"I am feeling really frustrated because I am having trouble getting past this level. I know that if I buy the fish boosters, then I would have an easier time of getting past this level. I am seriously contemplating hitting the buy now option on my ipad to purchase the boosters. I get frustrated with myself and disgusted at the game turn it off, and then go to play farm hero saga instead, which is similar to candy crush but it is a lot less difficult to spend money on it because it is easier to play." (P7)*

There are also many other comments from participants that demonstrate the struggle of not really wanting to spend any money in the game.

These results depict the kinds of experiences participants face when making a purchasing decision and demonstrate that self-regulation failure regarding purchasing decisions can occur as a result of repeated failures and the frustration of, for example, not completing a level at the verge of success.

Possible negative effects—Self-regulation failure has a significant impact on people's momentary affect and well-being (e.g., see (Hofmann, Luhmann, et al., 2014)). In our study, many of the participants reported experiencing negative feelings such as frustration and being mad at the point of purchase as a result of choice conflict. As discussed, many of the participants reported being frustrated in the game. A few participants also reported getting "too mad" (P4), impatient, and anxious. On the other hand, some of the participants consider spending money to be a form of cheating and purchasable extra moves as "extra cheats" (P67). P36 and P57, who made purchases in the game, described their feelings (respectively) as "not feeling like I will actually win, it feels like cheating," and "buying moves/pieces is cheating". People's positive feelings toward a game can be created by effective game design. On the other hand, some games may induce negative feelings about their progress and purchasing decisions in

the game (i.e., creating a situation that players are forced to push an "[I] give up" button or spending money to progress).

Conclusion

In this chapter, I presented the results of an MTurk study on a popular casual game to explore various factors impacting player behaviour, specifically, when they make decisions in the game. The study reveals that the amount of money players spent on in-app purchases were correlated with trait self-control. The findings of this study indicate self-regulation failure could play an important role in players' purchasing decisions when using Freemium games. I also demonstrated various self-regulation conflicts that players may experience in a game. The findings that were presented in this chapter also highlight the importance of considering the connection between self-regulation and gameplaying, especially in design patterns that are used in Freemium models.

The contribution of this chapter includes Empirical evidence regarding the relationship between self-regulation and the relatively new phenomenon of Freemium design models (Study 1) that revealed a connection between individuals' trait self-control and purchasing decisions. It also provides additional insights and observations regarding people's experience of self-regulation conflict and possible motivational and emotional struggles of these games.

This chapter focused on how design elements and mechanics can positively or negatively influence effective self-regulation. While this knowledge is helpful for researchers to study the connection between design mechanics and self-regulation success or long-term self-regulation improvement, there are limited possibilities for directly using some of these technology products to improve self-regulation. Therefore, researchers need to also focus on designing new technologies or new interaction techniques that could be integrated with current technologies, which is the focus of the following chapters.

Chapter 4
Interactive Technologies and Self-Control Improvement

In Study 1, I found that successful self-regulation plays an important role in players' purchasing decisions and demonstrated various self-regulation conflicts that players may experience in a game. In Study 2, I decided to investigate how playing games, in turn, might impact players' capacity for self-control. Therefore, I focused on designing games to measure and improve self-control, in addition to evaluating important factors of players' experience such as engagement and intrinsic motivation in a game that is designed to improve self-control.

Study 2: Investigating Game Mechanics That Target Players' Self-Control While Maintaining Engagement

Self-control is a critical component of effective goal pursuit. It allows us to make better, more mindful choices, and is associated with affective well-being and happiness in life (Baumeister et al., 1994; Hofmann et al., 2014). Self-control has been used as an umbrella term that encompasses a number of related constructs, such as self-regulation (Baumeister et al., 1994), delay of gratification (Mischel et al., 1989), impulse control (Tangney et al., 2004a), cognitive control and executive functions (Duckworth & Kern, 2011). A key question for scientists is identifying factors that can help people to regulate their behaviour more effectively in order to achieve academic goals, create healthy habits, prevent unethical behaviour in the workplace, resist drug or alcohol consumption, avoid excessive use of media, et cetera.

Games present a unique opportunity for people to use tasks that measure and improve their capacity for self-control, but not enough attention has been devoted to understanding how

we can incorporate various self-regulatory processes and techniques into games for such purposes. Despite these promising aspects for creating self-regulation interventions, using interactive designs has been limited mostly to approaches that did not consider design aspects of a self-control game (Anguera & Gazzaley, 2015). As a first step toward designing a game to exercise and measure self-control, I created a game to challenge various domains of self-control. I constructed a self-control activity in a game-like environment to investigate players' performance and experience in the game.

As previously discussed, constructing an activity that can effectively challenge self-control processes presents a number of challenges. First, self-control tasks that require using cognitive control and effortful inhibition of responses might be mentally taxing or depleting (Baumeister et al., 2007; Finkel et al., 2006; Hagger et al., 2010; Molden et al., 2012; Muraven et al., 1998), which can negatively impact a player's experience. Second, while I argue for using games that require considerable self-control to play, such games might create negative affect, decrease quality of motivation, or cause disengagement from the game. I therefore conducted a study to explore my self-control game to demonstrate that (a) it can significantly target a player's cognitive capacity for self-control, and (b) will not affect other important factors of positive or negative player experience, such as disengagement or negative affect.

In this work, I present the results of an initial user study, which showed that people exercised self-control in my game, which successfully challenged several self-control processes without reducing engagement, inducing negative affect, or undermining intrinsic motivation. This game essentially serves as a proof-of-concept that games *can* be designed to activate self-control processes without harming player experience. My results also indicated that people with different levels of self-control had different performance and player experience suggesting that games designed for self-control improvement or exercise could leverage this information to better target people with low vs. high levels of self-control through adjusting the difficulty of games by using adaptive game mechanics.

Self-Control Game Design

There are important advantages to using interactive technologies such as games for improving a person's self-control capacity and executive function. Self-control processes are often effortful and possibly depleting (Hagger et al., 2010; Muraven et al., 1998), which makes it particularly difficult to maintain engagement, motivation, and positive affect when engaging

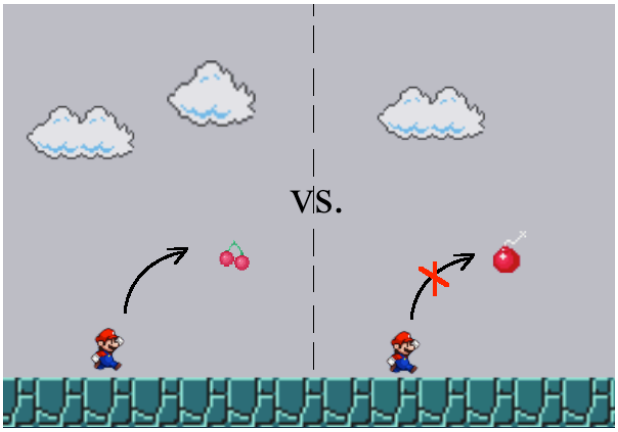


Figure 3. In *Save the Garden*, players exercise self-control by collecting fruit (left) and avoiding bombs (right). Players inhibit responses (e.g.) by jumping vs. not jumping.

in tasks requiring self-control. The motivational pull of videogames and their positive effect of momentary affective well-being (Przybylski et al., 2010; R. M. Ryan et al., 2006) make them a promising medium within which to embed interventions for self-control improvement. To explore the space of designing self-control games, I describe the design of my game, *Save the Garden*, and how I applied current theories of self-regulation and executive functions so that it targeted players' self-control.

Game Design

I used the Unity 4.5 game engine to design *Save the Garden* (Figure 4), a single-player platform game with two versions: one (*go/no-go*) was designed to engage different domains of self-

control, and another (*go*) was designed so that it did not require self-control (and acted as a control condition in our study). I incorporated familiar game mechanics and characters into the design, and it resembles many commercial games, such as Subway Run, Flappy Bird, Circle, and Amazing Ninja in its mechanics.

Go/No-Go Paradigm

I based the design of my self-control game on the go/no-go paradigm (Diamond, 2013), which is a commonly used paradigm in research on executive function (e.g., see Eigsti et al. (2006). A go/no-go task requires participants to respond to a stimulus by either choosing to act (go) or not act (no-go), and which is the "correct" choice alternates regularly. Because of this alternating pattern, the choice to not act requires withholding a response by inhibiting or overriding *prepotent* responses (e.g., in the presence of an *automatic* or *dominant* response (Hofmann, Schmeichel, et al., 2012; Miyake et al., 2000)).

The main goal in the first game (*go/no-go*) is to collect as many "good" items as possible and avoid collecting "bad" items. Therefore, players need to respond to items they want to collect (go events) and withhold a response by inhibiting or overriding prepotent responses to items they want to avoid (no-go events) (Casey et al., 2011; Eigsti et al., 2006). In the second game

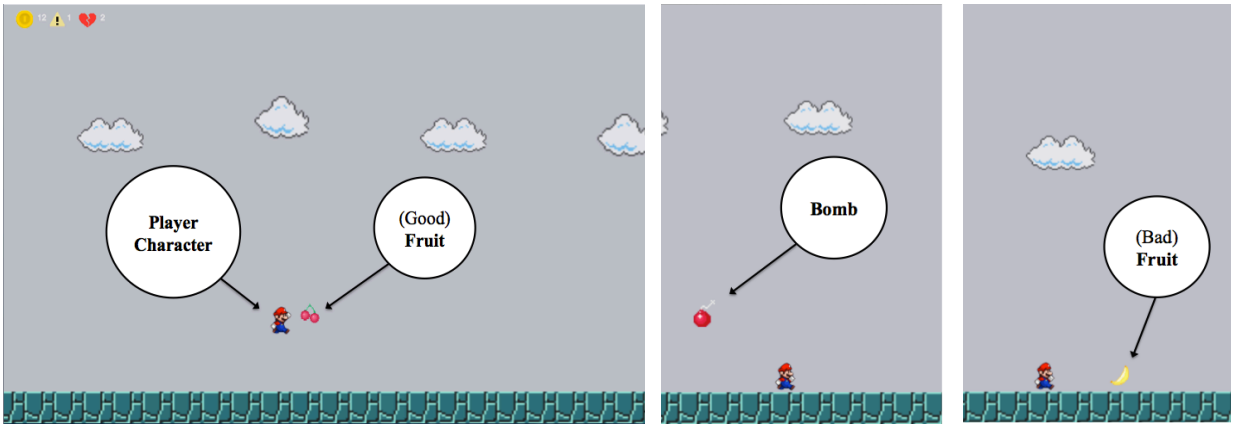


Figure 4. Screenshots of the game in go/no-go conditions of the study, including player character, (good and bad) fruits, and bomb items in the game. The player has jumped by pressing 'space' to collect a good fruit, has kept running to avoid a bomb, and needs to jump to avoid a bad fruit in this round of the game (from the left to the right snapshot respectively).

(*go*), which acts as a control in the study, the main goal is to collect as many "good" items as possible, without any items to avoid.

"Save the Garden"

In my game, called "Save the Garden," each player starts game rounds in a garden with various items in it (e.g., fruits, small bombs, background items, etc.). In the *go/no-go* version of the game, the character moves forward automatically, and game items appear on the screen as they move that either need to be collected or avoided by jumping using the space bar on the keyboard. Items can appear either at the same level or above the player, and so jumping or not jumping can alternately be required for collecting or avoiding. The type of item determines whether a person should collect or avoid an item (e.g., bombs should be avoided and good fruits should be collected). The use of a familiar game character (Nintendo's Mario) quickly communicates the narrative of the game.

A player in the *go/no-go* game condition collects all but one type of fruit (which has gone "bad" and must be avoided). There are six fruits in total, some similar in colour but not shape: apples, bananas, lemons, grapes, oranges, and cherries. The "bad" fruit changes every round and the player must also avoid bombs that have similar colours to some of the fruits in the

game.

I designed the elements of the game in both conditions to be as similar as possible, including collectable items, character, scenario, and general goal. A player in the *go* game thus plays the same game, but has no "bad" fruits or bombs. However, in pilot tests with only this change, participants found the game too predictable and expressed a lack of engagement. I therefore made a few small adjustments to the *go* game to decrease boredom: In the final "go" version of the game, fruits are situated behind or in front of semi-transparent trees (thus requiring some attention), characters can move back and forth (instead of automatic movement), and the fruits appear more regularly. I considered a variety of other mechanics, but finding a mechanic that is both engaging and has no systematic no-go response can be challenging. For example, platforms to jump on or across, action-at-a-distance mechanics (e.g., shooting guns/arrows), and other common platformer mechanics can require timing of when to "go" or "not go," thus conflating the two conditions.

In addition to scores, the game provides auditory feedback. For instance, collecting good fruits results in a coin-collecting sound, collecting bad fruits results in an error sound, and collecting a bomb results in a small flash effect in the screen with an "ouch" sound. These sounds are informational and help players to learn how to play.

Use of Self-Control in "Save the Garden"

While I base my design on the go/no-go paradigm, the game goes beyond using a single cognitive control task by incorporating more complex mechanics in a realistic game-like setting. Therefore, players need to use multiple interrelated components of self-control to perform well in the game. They need to use *working memory* to maintain, use, and update information about multiple unfamiliar fruits in the game to collect or avoid them. There is an additional *task switching* cost when the player starts a new round and the "bad" fruits change, which means the correct response in the first round could be an incorrect response

in the following rounds, and vice versa. Players need to use *inhibitory control* to inhibit various responses to avoid bombs and "bad" fruits. The game makes this inhibition more difficult by using similar colours for bombs and fruits. Furthermore, the ratio of randomized fruits varies in the game. Thus, players are required to use a broad range of self-control processes to perform well. It is also likely that players need to regulate their interfering thoughts or negative emotions (e.g., in-between rounds when they perform poorly in a round), especially when they compare their performance to previous rounds.

Generalizability of "Save the Garden"

One challenge in designing a game that incorporates self-control mechanics is to not lose the essence of what makes it a "game". Goals and objectives, rules, and decision-making that result in quantifiable and clear outcomes are considered to be central in many definitions of a game (Salen & Zimmerman, 2003).

"Save the Garden" satisfies each of these elements. Nonetheless, incorporating these mechanics into something more complex, like The Elder Scrolls: Skyrim or the Civilization series would require significant effort. Nonetheless, our proof-of-concept shows that games with simpler mechanics and lower fidelity, for example, games with similar mechanics (e.g., Subway Run, Super Mario Run, Temple Run) can incorporate these self-control mechanics. Future research could explore including self-control mechanics in more complex, higher-fidelity games, or explore other existing commercial games that may already incorporate some self-control mechanics (e.g., Virtual Cop, Ghost Blitz).

Studying Self-Control in "Save the Garden"

I wanted to investigate whether I was successful at designing a game that can challenge self-control, without negatively impacting other important elements of an effective self-control game, such as engagement, negative affect, and intrinsic motivation. In addition to these

primary goals, I examined the effect of player performance on each of these constructs. I also investigated individual differences in players' self-reported chronic levels of self-control to see whether these differences were related to performance in the game.

The primary goal of this study was to test whether I had in fact designed a game that could effectively challenge a range of players' self-control processes. Thus, my first research question was:

> RQ1. Do participants exercise self-control when playing the self-control (*go/no-go*) version of the game?

An additional consideration was whether challenging self-control processes might simultaneously undermine player experience. Therefore, my second research question was:

> RQ2. Does playing the self-control game undermine engagement and quality of player experience?

Furthermore, I wanted to explore how designers might account for a player's trait self-control. I therefore investigated the connection between trait self-control and two measures of performance (error rates and perceived competence) that could be used to adapt the game to be more optimally challenging, thus improving player experience. Thus, my last two research questions were:

> RQ3. What is the effect of trait self-control on performance and quality of experience?
>
> RQ4. How does performance affect the quality of player experience in self-control games?

Method

I conducted a lab study to examine these research questions related to the broad question of whether self-control games have the potential to be effectively used as a tool for practicing

and improving people's self-control capacity.

Participants

I recruited 45 university students (19 identified as female; 25 identified as male; 1 not specified) to participate in a study of "Game Playing Experience" through campus flyers. Participants were randomly assigned to one of two conditions (22 *go/no-go* condition; 23 *go* condition). All participants completed the study and were paid $10 for their time.

Procedure

I used a dual-task paradigm (Muraven et al., 1998) that examines the effect of one task in which people must exert self-control on an unrelated subsequent task that also requires self-control. This approach uses a between-groups design with half the participants in a self-control condition (*go/no-go*) and the other half in a control condition (*go*). The expectation in this paradigm is that exerting self-control in one task will result in poorer performance in the subsequent task (Muraven et al., 1998).

This effect has been theoretically attributed to different causes, such as depletion of a limited capacity for self-control (Baumeister et al., 2007; Muraven et al., 1998), a shift in motivational priorities and attention (Inzlicht & Schmeichel, 2012), or an opportunity-cost of an action (Kurzban et al., 2013). My primary objective, however, was not to investigate the underlying theory, but to provide initial confirmation that the manipulation is strong and effective enough to engage participants in a complex self-control task. Therefore, please note that I do not suggest that using this paradigm is necessary for future HCI researchers designing self-control games.

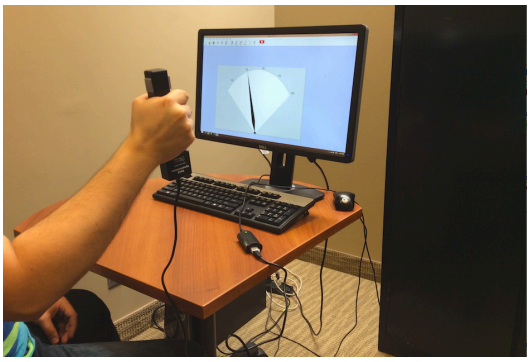


Figure 5. The digital hand dynamometer used to measure handgrip performance.

I used a handgrip task as the subsequent measurement task (using a digital hand dynamometer; Figure 5), which has been frequently used in dual-task paradigms (Finkel et al., 2006; Hagger et al., 2010; Molden et al., 2012; Muraven et al., 1998). The ability to hold a handgrip for a prolonged period of time is related to persistence rather than simple physical strength because the task requires endurance as an individual resists the urge to quit due to physical discomfort (Rethlingshafer, 1942; Thornton, 1939), although strength must be controlled for statistically. In our study, we used a threshold of ⅔ of a participant's maximum strength to account for variance in physical strength (Thornton, 1939).

The sequence for each participant was as follows (Figure 6): they first completed a handgrip task; then, after a short training session to familiarize themselves with the basic movements and features and the goal of the game, each participant played six rounds of one of the two game versions (about 15 minutes); then, there was an interim period to separate the two tasks (Hagger et al., 2010; Muraven et al., 1998) for about 2.5 minutes, in which participants completed the PANAS questionnaire that measures post-game affect before completing the second handgrip task. I collected data about affect in this interim period to better control for the effect of gameplay on the subsequent task in the dual-task paradigm, for example, in case negative affect from playing a difficult game affected handgrip performance (Muraven et al., 1998). Finally, each participant completed a longer set of questionnaires. Participants were

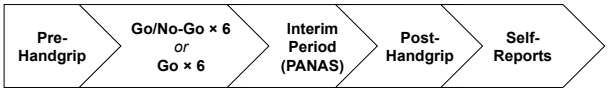


Figure 6. The experimental procedure.

not specifically instructed to compete with other participants in different sessions of the experiment nor they were aware of others' performance; however, being a game environment, participants were observed by the experimenter to be motivated to perform well in the game.

Self-Report Measures

After playing the game, participants completed the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988). I also asked participants about their level of engagement in the game by using the immersion item, "I really got into the game", from the Game Engagement Questionnaire (GEQ; Brockmyer et al., 2009). I also asked about how challenging and difficult participants found the game to be. Finally, participants completed a version of the Intrinsic Motivation Inventory (IMI) to mainly investigate interest/enjoyment, perceived competence, tension/pressure subscales. This scale was validated by McAuley et al. (1989) and serves to examine the quality of player experience. I calculated Cronbach's Alpha for each of the IMI subscales; all reliability scores were acceptable ($\alpha > .84$, for all four subscales).

Participants were also asked two questions about their experience in playing games in general and their average number of hours playing videogames per week. Participants were then asked to complete the 36-item Self-Control Scale (SCS) (Tangney et al., 2004a), a widely used scale to measure individual differences in trait self-control ($\alpha = .80$). They also completed a Morningness-Eveningness Scale (Horne & Ostberg, 1976), which is used to measure individuals' circadian rhythms, to control for any impact this may have had on their performance at different times of the day. Although, I did not analyze individual differences in Morningness-Eveningness on player experience and performance; this is reserved for future work.

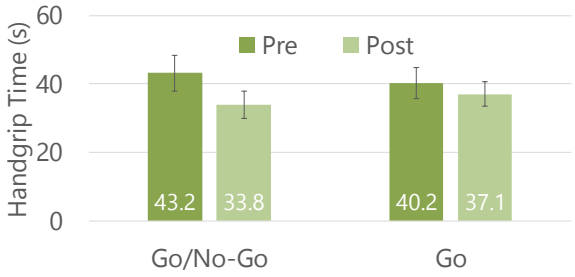


Figure 7. Pre- and post-condition handgrip times.

Game Performance

I logged the number of errors that a player made in each round of the game. The types of errors included: missing a good fruit (generally referred to as an omission error), collecting a bad fruit (a commission error), or hitting a bomb (another commission error). The appearance and order of items were pseudo-randomized in the game, and the total number of items in each session was constant. The *go/no-go* condition had all three types of errors, but the *go* condition only had omission errors (missing good fruits). In both conditions, I used the total error (error-total) as a measure of performance in the game.

Results

I first present the results of the primary dual handgrip task, followed by an analysis of the self-report measures. I then present an analysis of the performance data, first for the go/no-go condition, then for the go condition. In my analysis of performance data, I included correlational and mediation analyses that incorporated self-report measures. The order of this analysis is presented in roughly the same order as my research questions (RQ1–RQ4).

Handgrip

RQ1. Do participants exercise self-control when playing the self-control (go/no-go) game? I calculated

the difference between pre- and post-condition handgrip time (Δt) as a measure to calculate differences in handgrip performance, and compared the two groups using a *t*-test. There was a significant difference between the *go/no-go* and go conditions, t_{36} = 2.14, p = .039 (*go/no-go*: M = -10.7 s, SD = 14.1 s, *go*: M = -0.7 s, SD = 16.4 s; Cohen's d = .65), indicating that the participants in the *go/no-go* condition performed worse than those in the *go* condition as indicated by a larger decline in pre- to post-handgrip performance. I ran a 2 (game type: go, go/no-go) × 2 (measurement time: pre, post) mixed model RM-ANOVA on the handgrip time measure that confirmed the same significant interaction between game type and measurement time ($F_{1,36}$ = 4.59, p=.039, η_p^2=.116), which remained robust even when controlling for negative affect ($F_{1,36}$ = 4.14, p=.049, η_p^2=.106), positive affect ($F_{1,36}$ = 4.65, p=.038, η_p^2=.117), or Morningness-Eveningness ($F_{1,36}$ = 5.80, p=.021, η_p^2=.142) as covariates in the analysis. This result shows that playing the *go/no-go* version of the game resulted in worse performance post-game in a secondary handgrip self-control task than the *go* version.

Six participants did not accurately follow the handgrip performance procedure in either the pre- or post-condition handgrip tests, and one participant was unable to perform the handgrip task for health reasons, and so were excluded from the analysis[1].

Self-Report Measures

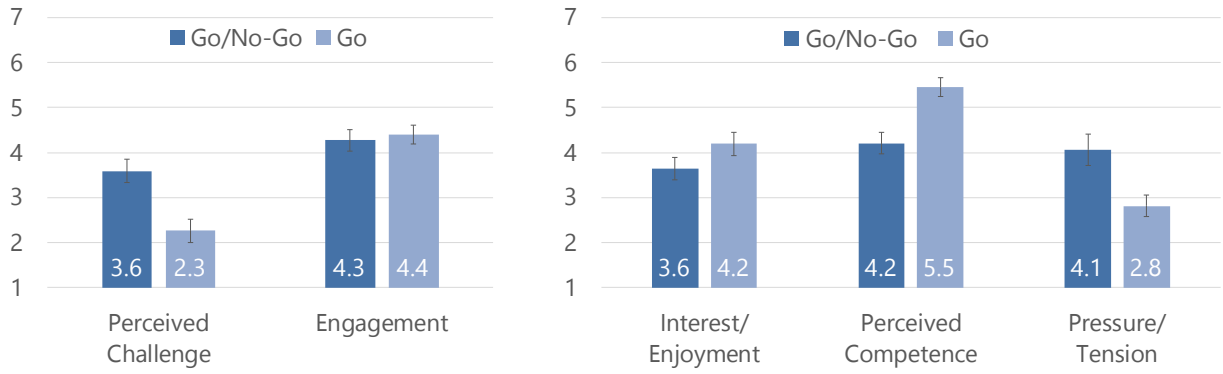
RQ2. Does playing the self-control game undermine engagement and quality of player experience? The

[1] The only individual differences between excluded participants and others, interestingly, were that they played higher hours of weekly video game playing, $F_{1,44}$ = 16.270, p <.001, d = 1.12. They also perceived themselves as more experienced in playing video games, $F_{1,44}$ = 4.590, p = .021, d = 1.25. Perhaps, this suggests that they might have been mostly just interested in playing a game in an experiment, therefore paid less attention to the non-game physical tasks of the experiment. Notably, the rate of exclusion in the current study (≈15%) was not high when compared to some other dual-task paradigms investigating depletion (e.g., an average of 26% exclusion across 23 labs (Hagger et al., 2010); also see (Graves et al., 2014)).

results of my analysis of player experience in the game are illustrated in Figure 8. I ran a multivariate analysis of variance (MANOVA) on the subscales of the self-report measures of player experience as the eight dependent variables with game type as a fixed factor. I subsequently ran protected independent-samples *t*-tests to compare responses between the *go/no-go* and *go* groups (using Bonferroni corrected $\alpha = .05/8 = .00625$). As expected, participants in *go/no-go* perceived the game to be significantly more challenging, $t_{43} = 3.12$, $p = .003$, $d = 1.93$. However, the perceived level of challenge in the *go/no-go* condition was still approximately at the mid-low level ($M_{go/no-go} = 3.6$, $SD_{go/no-go} = 1.5$; $M_{go} = 2.3$, $SD_{go} = 1.4$, Figure 8.a). There was no significant difference in the post-game reported level of engagement (immersion) between the two groups, $t_{43} = 0.09$, $p = .77$, *ns*., and both groups indicated mid-level engagement with the game (Figure 8.a).

I found no significant difference between the groups in post-game reported interest/enjoyment, $t_{43} = -1.56$, $p = .13$ ($M_{go/no-go} = 3.6$, $SD_{go/no-go} = 1.2$; $M_{go} = 4.2$, $SD_{go} = 1.2$, Figure 8b). Participants in the *go* condition, as expected, had higher perceived competence about their performance in the game than the *go/no-go* group $t_{43} = -3.88$, $p < .001$. However, both groups indicated at least a medium level of competence, $M_{go/no-go} = 4.2$, $SD_{go/no-go} = 1.2$; $M_{go} = 5.4$, $SD_{go} = 1.0$. Notably, participants in the *go/no-go* condition reported experiencing higher tension and pressure when playing the game, as shown in Figure 8b, $t_{43} = 2.98$, $p = .005$, $d = .88$, even though their pressure/tension levels were not high ($M_{go/no-go} = 4.1$, $SD_{go/no-go} = 1.6$; $M_{go} = 2.8$, $SD_{go} = 1.2$). Finally, there was no significant difference in post-game negative affect, $t_{43} = 0.71$, $p = .49$, *ns.* ($M_{go/no-go} = 1.46$, $SD_{go/no-go} = .38$; $M_{go} = 1.39$, $SD_{go} = .35$)., or positive affect, $t_{43} = -.243$, $p = .81$, *ns.* Notably, these results show that self-reports on engagement, enjoyment, and positive or negative affect were not statistically different between the *go* and *go/no-go* conditions, despite participants exerting self-control in the *go/no-go* game.

Go/No-Go Performance & Correlations



(a) Perceived Challenge/Engagement

(b) Intrinsic Motivation Inventory

Figure 8. Player experience and Intrinsic Motivation Inventory results on both conditions. Error bars represent ±1 standard error of the mean.

In the *go/no-go* group, the proportion of errors was calculated as the sum of three types of errors across all the rounds (error-total) divided by the total number of items. (M = 9.4%, SD = 4.2%,Figure 9), which showed an acceptable internal reliability (α = .82). The *go* condition had only one type of error, and so I analyzed data from both groups separately. I conducted planned pairwise comparisons of sequential rounds (5 total comparisons) to explore player performance, which revealed significant differences between rounds 1 and 2, $t_{21} = 2.9$, $p < .01$, and rounds 2 and 3, $t_{21} = 2.4$, $p = .02$. This pattern is consistent with a learning effect where performance improves until round 3 and then remains consistent (Figure 9).

To investigate the relationship of performance with player experience and trait-level of self-control (RQ2–RQ3), I conducted correlational and mediation analyses.

Correlational Analysis

RQ3. What is the effect of trait self-control on performance and quality of experience? Pearson correlations indicate that participants with higher levels of trait self-control had higher levels of perceived competence ($N = 22$, $r = .466$, $p = .029$). Notably, trait self-control was also correlated with fewer errors ($N = 22$, $r = -.413$, $p = .056$), and lower perceived challenge in the game ($N = 22$, $r = -.418$, $p = .053$), but did not reach significance ($p < .06$). The total number of errors in the game was not correlated with perceived experience in video game playing ($N = 22$, $r = -.111$, $p = .623$) or number of hours played per week ($N = 22$, $r = .093$, $p = .679$). This result shows that trait self-control predicted game performance and perceived challenge for the *go/no-go* game.

RQ4. How does performance affect the quality of player experience in self-control games? Players with fewer total errors had significantly higher perceived competence ($N = 22$, $r = -.588$, $p = .004$) as expected. Players with fewer errors also had significantly higher levels of interest/enjoyment in the game ($N = 22$, $r = -.487$, $p = .021$), but did not experience a significant difference in pressure or tension ($N = 22$, $r = -.281$, $p = .205$). This indicates that game performance impacted the level of perceived competence and enjoyment in the *go/no-go* game.

To investigate how each error type in the game might have influenced the level of perceived

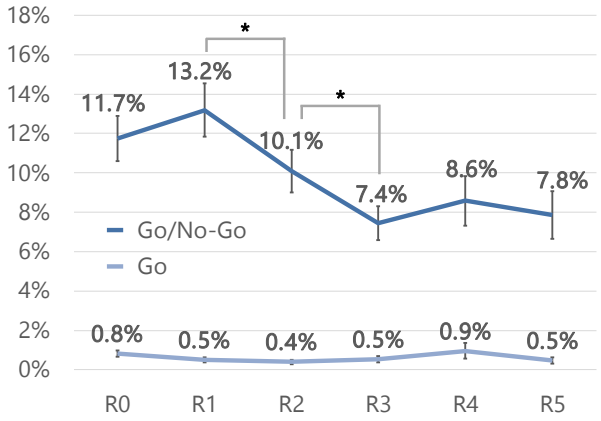


Figure 9. Performance in the go/no-go and go conditions. Participants performed worse in early rounds, and improved in later rounds, but only in go/no-go. *p<.05

competence and enjoyment, I also analysed the relationship between omission errors (type1: missing a good fruit), and commission errors (type-2: collecting a bad fruit, type-3: collecting a bomb) with IMI measures. Results show that all error types contributed to the level of perceived competence in the game. Perceived competence was significantly correlated with number of missed good fruits ($N = 22$, $r = -.427$, $p = .047$), collected bad fruits ($N = 22$, $r = -.562$, $p = .006$). It was also correlated with the number of collected bombs ($N = 22$, $r = -.418$, $p = .053$) although did not reach significance. Also, the level of interest/enjoyment in the game was correlated with all error types though did not reach significance: number of missed good fruits ($N = 22$, $r = -.410$, $p = .058$), collected bad fruits ($N = 22$, $r = -.379$, $p = .082$), and collected bombs ($N = 22$, $r = -.382$, $p = .079$).

Mediation Analysis

I further investigated the relationship between trait self-control, players' game performance (error-total), and their perceived competence in the game using mediation analysis (Figure 10). The level of trait self-control can directly predict higher perceived competence, $\beta = 1.10$, ($CI = .13, 2.07$), $t_{21} = 2.4$, $p = .03$. As previously mentioned, trait self-control predicts the total number of errors (performance), $\beta = -2.43$, ($CI = -4.93, .07$), $t_{21} = -2.0$, $p = .056$ which itself is a significant predictor of perceived competence, $\beta = -.236$, ($CI = -.39, -.09$), $t_{21} = -3.3$, $p = .004$. I used hierarchical regression analysis to examine the effects of trait self-control when controlling for game performance. The direct prediction of trait self-control does not stay significant, $\beta = .63$, ($CI = -.32, 1.59$), $t_{21} = 1.39$, $p = .18$. A clear limitation of this analysis is the sample size; however, I decided to include this analysis as an initial investigation of this important relationship. This result shows that game performance (error-total) mediates the effect of trait self-control on perceived competence in this game. The result of a bias-corrected accelerated bootstrap, that adjusts bias or skewness in its distribution, also confirms the same level of significance reported in Figure 10.

Go Performance & Correlations

Although the *go* condition requires some degree of attention, players had a low rate of error (M = 0.45%, SD = 0.80%), and there was no significant difference between the rounds ($t_{21} < 1.74$, $p > .09$). Interestingly, players in the *go* condition who had higher trait self-control experienced more positive affect after playing ($N = 23$, $r = .414$, $p = .050$). In general, participants in the *go/no-go* condition found the game more challenging than those in the *go* condition (see Self-Report Measures). However, in the *go* condition, the reported level of engagement is correlated with how challenging they found the game ($N = 23$, $r = .407$, $p = .054$) although did not reach a significant level.

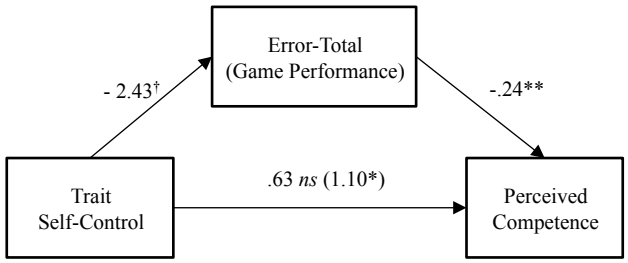


Figure 10. The mediation analysis of the relationship between trait self-control, perceived competence, and game performance. Numbers represent unstandardized beta values. N=22, †p<.06, *p<.05, **p<.01

Discussion

Important findings of this study are summarized as follows:

- Playing the *go/no-go* version of the game resulted in worse performance post-game in a secondary handgrip self-control task than the *go* version.
- Despite exerting self-control in the *go/no-go* game, self-reports on engagement, enjoyment, and positive or negative affect were not statistically different between *go* and *go/no-go*.
- Participants reported higher perceived challenge and higher pressure/tension in the

go/no-go condition.

- Trait self-control predicted game performance and perceived challenge for the *go/no-go* game.
- Game performance impacted the level of perceived competence and enjoyment in the *go/no-go* game.
- Participants had a pattern of play in the *go/no-go* game with improved performance in the self-control task we provided, but similar differences between rounds were not observed in the *go* group.
- Trait self-control predicted perceived competence, but was mediated by game performance for *go/no-go*.

The results of the study are promising and show the possibility of designing self-control games that engage a broad set of self-control processes, without negatively affecting player experience or causing disengagement. In particular, this game allowed people to exercise self-control by engaging players in multiple domains of self-control processes in a themed self-control exercise task within a realistic game-like setting. Differences in handgrip performance show that the *go/no-go* group exercised effortful self-control.

My results showed a similar rate of error as other research with simpler *go/no-go* paradigms (e.g., (Eigsti et al., 2006)). However, the current work adds to these results by demonstrating that players reported an acceptable level of engagement with the game that remained consistent as time progressed, and performance did not drop in later trials, for example, as the result of boredom. Notably, the level of engagement was not significantly correlated with any other factor, including level of trait self-control or number of errors in the game that required self-control. This result shows that it may be possible to engage players with different levels of self-control, which paves the way for further investigation into the design of games that target self-control, but also allow for long-term engagement.

These results also indicate that the level of self-control of players in the *go/no-go* condition can predict performance in the game. This finding is corroborated by the result that players with higher trait self-control perceived the game as less challenging. These results have two important implications: 1) They provide insight on the possibility of designing games for improvement in general domains of self-control, even using an activity that does not use particularly difficult challenges; 2) It shows initial evidence for the possibility of measuring trait-level self-control that could be used in an adaptive design to meaningfully and dynamically adjust the challenges with respect to both the level of self-control and progress in the game. For example, players that are performing well are likely to be high in trait self-control, and the game can adjust to present more challenging self-control tasks (e.g., as in: Yannakakis & Hallam, 2009). This technique may be valuable when designing games to improve a person's self-control capacity and executive functions, and usually cannot be achieved by more traditional cognitive training tasks (e.g., Saunders et al., 2018; Duckworth & Kern, 2011). The purpose of these results is not to introduce a new methodology to measure self-control in games, but to encourage future researchers to consider this as a strong possibility for designing self-control games.

Moreover, these results suggest a connection between specific measures of performance (omission and commission errors) and both perceived competence and level of enjoyment. Thus, this dynamic adjustment may also better target players' basic needs, and this game demonstrates low-level performance measures that could be used in this manner.

One risk of designing a game that targets self-control is that people with lower levels of self-control can potentially experience lower perceived competence. For instance, as they are less capable of regulating their negative thoughts or moods (Sansone et al., 1992), they may require special mechanisms (e.g., more positive feedback) to mitigate and increase perceived competence. However, mediation analysis showed that the number of errors (game performance) mediated the effect of self-control on perceived competence in the game, which

indicates that players have a fairly accurate perception of their competence in the game based on the information they receive. Therefore, promisingly, it may not be necessary for a designer to incorporate special in-game mechanics to address players with low trait self-control.

Limitations and Future Work

This work relies on an underlying theory of self-control that involves the development of several self-control processes. While improvement of any one of these processes has the potential for numerous positive effects, especially if a person has known weaknesses in that process (Joaquin A. Anguera & Gazzaley, 2015; Hofmann, Schmeichel, et al., 2012), it is important to note that, although people with higher cognitive capacity for self-regulation are better at self-regulation of their behaviour (Diamond, 2013; Hofmann, Schmeichel, et al., 2012), this might not reflect all aspects that lead to success in self-regulation. In other words, although effortful inhibition of responses to temptations might be a necessary condition and an essential mediator to succeed, it might not be a sufficient condition nor the most effective way to self-regulate behaviour (Fujita, 2011; Milyavskaya & Inzlicht, 2016).

On the other hand, recent studies point out that people with higher trait self-control can strategically avoid temptation and experience less temptation in the long-run, as they select and evaluate situations they face in life better than others (Duckworth et al., 2016; Ent et al., 2015; Milyavskaya & Inzlicht, 2016). Thus, there is some preliminary evidence that practicing a variety of self-control strategies in a game-like environment has the potential to improve self-regulation more broadly, and thus lead to success in other parts of life.

There are many promising avenues of future work in the endeavour to create game-like environments for self-control improvement. In particular, games have the potential to create real-life situations and scenarios, where players can adopt different short-term and long-

term goals. Designing games in which players experience real choices and choice dilemmas have the potential to lead to meta-cognitive improvements in life. Future work could explore how integrating these more realistic dilemmas with self-control challenges might better simultaneously target improvements that lead to successful self-regulation.

Conclusion

This experiment has mostly focused on positive aspects of targeting people's self-control for the purpose of self-control improvement. However, there might be short-term costs to playing such games. For instance, incorporating self-control elements into games might have an effect on problematic gaming behaviour. Self-regulation failure is associated with various aspects of problematic online behaviour (Haagsma et al., 2013; Seay & Kraut, 2007) that could negatively impact players both during and after play. Therefore, practicing self-control might have an impact on some short-term behaviours and decisions, especially in-game, for example, making unwanted in-app-purchases as the result self-regulation failure (Soroush et al., 2015). It is therefore important to investigate other effects of using self-control game elements on players' gaming experience and behaviour, for example, how this knowledge could be exploited by game designers to indulge players into spending more money while playing games.

However, even though self-control practice over a period of gameplay might cause cognitive depletion or a shift in attentional and motivational processes and therefore affect subsequent activities or decisions (Baumeister et al., 2007; Inzlicht & Schmeichel, 2012; Kurzban et al., 2013), these effects are not expected to carry over to a longer period of time (e.g., the whole day). That is, practicing self-control does not necessarily result in a long period of cognitive fatigue (Inzlicht & Berkman, 2015). A useful metaphor of the strength model of self-control is its resemblance to a muscle (Baumeister et al., 2007). It can be thought of as improving muscle strength at the short-term cost of using muscles—the costs of practicing self-control

games can be thought of as the short-term costs of exercising that may lead to long-term benefits.

Videogames have the potential to measure and improve self-control. The current experiment suggests that there are numerous possibilities for designing self-control games beyond existing approaches. This study makes a number of contributions to the design and evaluation of self-control games. In particular, it presents findings that shows it is possible to engage players in self-control games without creating a negative player experience or undermining intrinsic motivation. The current study is a positive step towards further investigation of games that aim to improve self-control, which is an endeavour that has the potential to improve people's ability to pursue their goals.

This chapter explored the use of interactive technologies to study and improve self-control processes. It includes an empirical study that investigates designing and testing a self-control game to engage a broad range of self-control processes, and its effect on player experience.

The contributions of this chapter includes designing of a self-control game (Save the Garden) that targets various self-control functions and allows for empirical evaluation and conducting an empirical study regarding using self-control games to target and improve self-control by considering players' experience and engagement (Study 2) that showed some preliminary findings regarding using self-games for challenging and improving mechanisms and practicing self-control.

In the next chapter, I have focused on the controversies surrounding the self-control improvement topic. The chapter includes a critical discussion in the form of a commentary regarding recent controversies about the resource model of self-control (i.e., ego-depletion model of self-control) and similar approaches to improve self-control or basic executive functions.

Chapter 5
Commentary: Ego-Depletion and Self-Control Improvement

Study 2 focused on how we can incorporate and target game mechanics to challenge and impact a person's cognitive-control capacity, which can be crucial when a person needs to improve such mental functions. One of the major issues with adopting this approach, however, is the controversies surrounding self-control and cognitive control improvement primarily in ego-depletion research. Therefore, this chapter focuses solely on a brief commentary to highlight the main issues surrounding controversies and discuss possible solutions, in order to move this research forward.

Critical Review of Ego-Depletion Debate

As discussed in the first and second chapters, there are controversies surrounding the ego-depletion model and its major claims, namely the findings that suggested exerting self-control in one task results in doing worse in a second task, and that practicing self-control tasks regularly would improve self-control over time (Inzlicht et al., 2014; Inzlicht & Berkman, 2015; Melby-Lervåg et al., 2016; Melby-Lervåg & Hulme, 2013). The promising aspects of this model have been controversial and questioned by new meta-analyses (Carter et al., 2015; Carter & Mccullough, 2014) followed up with two failures of simultaneously replicating one or several existing ego-depletion studies (i.e., multi-lab pre-registered replication) notably by advocates of the theory (Friese et al., 2016; Hagger et al., 2014; Inzlicht & Berkman, 2015; Miles et al., 2016).

The controversies regarding replication of ego-depletion and working memory findings, as previously mentioned, created limitations on opportunities for further applied work that

completely relies on the aforementioned theories and approaches. One major contribution that could be provided by those who are working on related topics is identifying factors that could resolve these controversies through uncovering critical issues with the current state of work on ego-depletion and pointing out opportunities for new methodologies or paradigms to study the phenomenon more accurately than has been previously done. This section first includes a brief critical review of some of the major issues and oversights in methodological and theoretical aspects of this research, and then accordingly argues for the possibility of settling some of the controversies by reconsideration of previous methods and hypotheses, especially by using games as a tool for achieving these purposes. This review also specifically argues for the use of digital technologies that allow for easier simultaneous multi-lab pre-registered replication of the experiments.

Theoretical and methodological shortcomings and oversights

It is important to discuss several underlying issues in the theory and methodologies used to study the resource model, which to some extent have been pointed out by other researchers, for instance, the appropriateness of the dual-task paradigm for testing such hypotheses, or the need for better conceptualization of ego-depletion (Friese et al., 2019; Inzlicht & Berkman, 2015). Some of these issues, however, need to be better highlighted or require further discussion.

Theoretical shortcomings

One of the biggest criticisms that has yet to be addressed by advocates of the theory is regarding conceptualization of ego-depletion (Inzlicht & Berkman, 2015), that is, whether depletion is mostly a perception of fatigue, for example, as the result of a shift in emotional-motivational mechanisms (Inzlicht & Schmeichel, 2012; Molden et al., 2012) or it is a state of

momentary mental fatigue (Inzlicht & Berkman, 2015). This difference could entirely change the possibilities of using various paradigms for studying ego-depletion, since one indicates that it is possible to overcome the momentary effects of depletion perception, but the restoration process would not be as easy when there is a biological root to the effect. Even though this difference has been pointed out by others, it is argued in this section that we first need more accurate methodologies (e.g., when designing a depleting task) to make a distinction between these two possible phenomena and that both could concurrently happen. The importance of this distinction will be discussed more later in this review.

Even though not originally intended (Baumeister et al., 1998; Muraven et al., 1998), ego-depletion theory has not addressed the theoretical issues. This criticism brings up a general and more substantial problem, that is, the resource model of self-control was just shy of a black-box theory for a decade, similar to classic behaviourism approaches (Bunge, 1963), without closely looking into observable aspects of cognition, emotion, and behaviour when using a dual-task paradigm methodology. This approach then is fundamentally flawed in terms of proving any additional insight into this topic.

Methodological oversights and ambiguities

There are also various methodological issues in the way that these experiments have been conducted. As previously mentioned, the dual-task paradigm consists of two sequential tasks including a first one that uses self-control and is depleting, which makes it difficult for a participant to perform the second task that requires either (1) exerting self-control (e.g., in cognitive control tasks such as a stop signal or Stroop task) or (2) maintaining attention and control when having distracting or interfering impulses (e.g., when holding a handgrip). Therefore, when considering *effortful* control to be the reason for depletion, the first task needs to be effortful. However, a considerable number of experiments that tested the

paradigm have used tasks that involve decision making, affect regulation, or thought regulation, and therefore have introduced a series of questionable methodologies to ego-depletion literature (for a review, see: Hagger et al., 2010). For example, in the "white bear" paradigm (i.e., a classical thought control experiment), participants are instructed to not think about white bear (i.e., an arbitrary choice of an animal to not think about) for a certain period of time. Using this task as a self-control depleting task carries a questionable underlying assumption that the majority of participants will use effortful control to continually suppress the somewhat vivid thoughts of a white bear, instead of applying a simple strategy of thinking about a different topic, that is, a simple distracting strategy that people often use to distract themselves when dealing with unwanted thoughts (Mischel et al., 1989), especially in the absence of reminder stimuli to make distraction more difficult.

Other examples of using depleting tasks that in reality may not be depleting at all, are choice tasks and affect regulation tasks that similarly assume a continual exertion of self-control (Hagger et al., 2010) as researchers conveniently do not consider that such tasks could be completed without a significant burden on cognitive control. For example, choice tasks (Bruyneel et al., 2006; Hagger et al., 2010) may require little to no cognitive control in the period of an experiment. Also, on the other hand, when considering video-watching tasks, participants are watching a video while they are, for instance, instructed to ignore distracting words that appear on the screen (Fischer et al., 2008; Schmeichel & Vohs, 2009) or instructed to emotionally remain neutral when watching a movie with interesting or upsetting scenes (e.g., see Hofmann et al., 2007). Unfortunately, no convincing evidence or argument (beyond references older research) has been provided in these experiments to support that participants require effortful attention or cognitive control in video-watching tasks that involve distracting words appearing on the screen. In other words, we cannot confidently assume those pop-up words are actually interfering with attending to the content in a way that requires considerable attentional resources. Also, when considering video watching that

requires maintaining a neutral reaction (e.g., a neutral facial expression), the procedure could simply be completed by not fully engaging or immersing in the video, and do not necessarily need an effortful suppression of emotions. However, researchers have uncritically borrowed these paradigms without providing convincing arguments to support their choices.

Notably, these are some of the commonly used tasks in ego-depletion literature. Others have also pointed out a need for further justification for more peculiar choices of depleting tasks such as using standardized tests (that supposedly are mentally taxing) and maintaining balance on one leg (Lurquin & Miyake, 2017; Tyler & Burns, 2008), and pointed out the need for justification of having similar first and second tasks (Lurquin & Miyake, 2017). However, as discussed, these criticisms are ultimately an understatement of broad methodological issues that are rooted in the lack of clarity that exists in theoretical aspects of ego-depletion research. That is, even if there is a probability that some of the mentioned tasks are mentally taxing, they are not necessarily using considerable impulse control (or cognitive control that is assumed to be essential for consuming mental resources related to self-control or some other *unknown* source of energy), and indeed are contradictory with the underlying theories that are provided by ego-depletion advocates.

In addition, there are important aspects of ego-depletion that are often ignored by researchers. For example, the first meta-analysis of ego-depletion experiments shows a considerable effect-size difference when an "interim period" is incorporated between the first and second tasks (see Table 3 in Hagger et al., 2010); Δd=.30 for using filler tasks or breaks, and 0.20 for using questionnaires), which is largely ignored in later discussions of the topic. Regardless of how we interpret this difference, these kinds of oversight in addition to other issues in experimental designs indicate the need for reconsidering some of the assumptions in experimental designs when studying this topic in order to have a clear picture of research questions and hypotheses that are actually tested when conducting ego-depletion experiments.

Muscle metaphor

It is possible to argue that the most insightful aspect of the original conceptualization of the resource model may be using the metaphor of a muscle to describe ego depletion and the possibility of self-control improvement by exercising self-control tasks regularly (Baumeister et al., 2007), the same way that people workout regularly to strengthen physical muscles. Ironically, this is the only aspect of the theory that is mostly ignored by both advocates and critics of the theory. This metaphor is not to be used literally for conceptualizing mechanisms of ego-depletion and self-control improvement, but to give thought to what depletion is and what causes it, in order to speculate and generate new hypotheses that help test ego depletion and discover if the ego-depletion effect is indeed real.

For example, there could be similarities between how momentary and lasting fatigue happens when we use our physical muscles and cognitive control. For instance, a naïve observer of a physical workout process can argue: (1) there are momentary or lasting discomforts in the muscles when we use them without warming up, or when we use irregular or intense moves to exercise, (2) a workout that is not challenging when considering a person's strength level will not create momentary or lasting fatigue, and only might create this effect if continued for a long time, (3) momentary or lasting fatigue happens often when we consider our strength level or perhaps when we engage a muscle to the extent that we are pushing it to the limit (i.e., close to its maximum strength), and (4) accordingly, improving the psychical strength of muscles happens when we use them regularly, and often when they are significantly and carefully challenged. Therefore, not all exercises are *suitable* for improving physical muscle strength.

Now, a naïve observer of how a person uses mental control (e.g., cognitive control and attentional control processes) might make somewhat similar observations or assumptions. We can explore how we translate such observations from the functions of psychical muscles to

cognitive control processes in order to generate research questions and speculate new hypotheses. It includes the following questions:

- When participants maintain cognitive control, is it appropriate for them to start the main task right away, or do we need a trial phase (i.e., a warm-up)?
- Can we then distinguish between *momentary discomforts* in mental processes and *momentary mental fatigue* when studying depletion effect? This assumption would require us to think about limitations of existing methodologies that makes it impossible to address the issue.
- Can we identify or design exercises that are *suitable* for self-control improvement, to appropriately challenge and improve cognitive control processes?
- Can cognitive tasks that require intense impulse control without a realistic engagement of cognitive control processes be considered good choices for testing depletion or exercising self-control? Do these tasks only function as irregular or intense practices of non-central self-control functions (with possibly no realistic behavioural and real-world implications (Saunders et al., 2018), which result in mental discomfort and an aversive state (Baumeister et al., 1998; Cooper et al., 1978; Zanna et al., 1976) and could they then only translate into motivational shifts that change the preference to continue secondary tasks?

Considering these simple observations would indicate there are still major unexplored and critical questions. It also shows that the complexity of the phenomenon is underestimated, and there is an urgent need for more carefully calibrated methodological designs and hypotheses that could provide us with minimum required insights to understand depletion.

A way forward

One of the major appeals of the resource model of self-control that resulted in its popularity

arguably was that it offers a clear methodology for directly manipulating self-control variables for experiments. This definition heavily relies on broadly considering ego-depletion as a type of mental fatigue (i.e., its reliance on mental resources). Alternatively, considering depletion as an affective-motivational state that could be more easily overcome limits the applicability of using such methods as a reliable self-control manipulation. Therefore, settling this controversy has vast implications for future theoretical and applied work that could benefit from manipulating self-control.

Therefore, as previously pointed out, one question that needs to be incorporated in future hypotheses and methodological designs is about the nature of depletion. We need to investigate if depletion is just the perception of depletion (e.g., an aversive state or a lack of motivation) or is more than a perception and is in fact a type of mental fatigue (e.g., a mental mechanism that creates a state of fatigue to prevent mental processes from fully functioning before restoration).

The initial meta-analysis of ego-depletion studies reported a medium to large effect size of d = .62 (Hagger et al., 2010) ranging from .40 to .86 when considering different tasks or procedures. A point that is largely ignored is that if we consider depletion to be a mental fatigue, we should clearly be able to create considerably larger effects sizes, for example, effect sizes larger than 2. Such experiments would also irrefutably settle the controversies that question if the effect is actually real. Creating these effect sizes would require both more difficult and longer depleting tasks, which need additional considerations such as simultaneously creating possible confounds. For example, using longer and more challenging tasks increases the likelihood of causing negative affect or aversive states (Baumeister et al., 1998; Zanna et al., 1976) especially in the lack of proper motivation to continue the task. These considerations for the choice of the depletion task makes games (or appropriately gamified tasks) an essential tool to use for these experiments, as games highly engage players and maintain quality of motivation (Deterding & Dixon, 2011; R. M. Ryan et al., 2006). Game players are known to be

more intrinsically motivated when engaging with well-designed games (Przybylski et al., 2010; Ryan et al., 2006), even when facing extremely intense and challenging in-game situations for a substantially long period of time. Another important factor in designing these experiments is making it possible for other researchers to replicate the exact procedures used in a study; therefore, digital technologies such as videogames could greatly facilitate the possibility for all researchers across the world to replicate a study while maintaining the exact experimental procedures, which has been an important and challenging factor in pre-registered multi-lab replications (Hagger et al., 2014).

Overall, researchers have pointed out various considerations we need to have regarding ego-depletion studies. This review elaborated on additional issues and oversights in self-control research regarding shortcomings in conceptualizations and methodologies by analyzing the current state of research. This review also explored and suggested reconsiderations in methodological and theoretical aspects of ego-depletion research that makes it easier to settle some of the controversies and to move the research forward. In the following chapters, I will focus on using interactive technologies to more directly impact self-regulation mechanisms, focusing in particular on challenges that people experience when regulating desires and behaviours, by exploring new interaction techniques and designing interactive technologies that help people resist the impact of tempting situation or object, for example, when facing tempting foods. In the next chapter, I will briefly review the research regarding the connection between psychological distance and self-regulation to lay the groundwork for my approach to use interactive technologies as a means to battle temptation and practice self-regulation.

The contribution of this chapter includes A commentary on the controversies related to the ego-depletion model, which provides a high-level perspective regarding the current state of research and issues to study and design for cognitive control and self-control improvement.

Chapter 6
Self-Regulation and Psychological Distance

There is very limited knowledge about how one can use design elements and techniques to target these broader self-regulation functions and strategies that help us achieve our goals, especially when we consider challenges of individuals when they face strong and unwanted desires of tempting situations and objects. Designing technologies that effectively target self-control processes could have major benefits for individuals, using interactive technologies to impact self-regulation strategies for regulating desires and behaviours *directly* therefore is the main focus of my research in this chapter and the following chapters. As previously mentioned, having such broad approaches to self-regulation improvement by using interactive technologies provides the possibility of creating simulated situations and visual techniques for assisting self-regulation success by helping people to more effectively practice self-regulation.

This chapter and the following chapters focus on creating and studying interactive visual techniques that impact the psychological distance at which a person experiences a tempting situation. It includes designing simple techniques to battle temptations and boost self-regulation in the next three studies that investigate how we can use these visual techniques to help people *distance* tempting stimuli and make it less tempting by mediating what they experience in a self-regulation conflict situation.

Before presenting the design techniques and empirical studies that were conducted to test them, I first discuss in this chapter the role and importance that psychological distance has in understanding self-regulation.

It includes a critical review of the concept of psychological distance, which has informed my own study designs and decisions, and provides insights for future researchers studying

psychological distance.

This chapter focuses on creating and testing interactive design techniques for improving self-regulation through visual techniques that impact the psychological distance at which a person experiences a tempting situation. It first includes a commentary that discusses psychological distance as a crucial factor to consider in studying and designing for self-regulation improvement. It then explores designing techniques that could influence various dimensions of psychological distance for the purpose of helping people in tempting situations and ultimately improving self-regulation of desires and behaviours.

Psychological distance as a central factor in understanding self-regulation

Self-regulation involves complicated intertwined processes that are found in most activities and situations of our daily life. Researchers have adopted various perspectives for explaining and studying motivational and self-regulatory processes as reviewed in chapter 2. In this brief commentary, a point of view is presented that argues *psychological distance* is a central factor in diverse processes of goal-pursuit and unifies a wide range of self-regulation processes and strategies that people use when pursuing their goals or struggling with resisting temptations and desires. This commentary does not provide a comprehensive review of psychological distance in the psychology or self-regulation literature and related work, but specifically points out its importance as a central factor and discusses its role in designing various techniques that can be used to intervene in tempting situations or for improving self-regulation by utilizing existing technology.

Psychological Distance and Distance Dimensions

Perceptions of distance, such as one's distance from an object, person, or situation, are

subjective and could have various dimensions, such as spatial (i.e., the perceived physical distance), temporal, or hypothetical distance (Lewin, 1951; Y Trope & Liberman, 2003; Yaacov Trope & Liberman, 2010). Together, these different types of distance can be understood as the *psychological* distance a person feels from something. People use the conceptual metaphor of *spatial distance* (Boroditsky, 2000; Casasanto & Boroditsky, 2008; Landau et al., 2010) to think about how close or far something is situated from the self even when describing temporally distant objects or events, e.g., by describing an event happening soon as being *close* in the future (Boroditsky, 2000; Casasanto & Boroditsky, 2008).

Pervasiveness of Psychological Distance

The concept of *distance* has been considered in higher-level self-regulation theories, such as the control model (i.e., cybernetic model) (Carver, 2006; Carver & Scheier, 1981, 1982), which suggests individuals pursue a goal (i.e., a desirable end state) by attempting to increase their distance from undesirable end states (i.e., avoidance) or decrease their distance from desirable end states. People use these perceptions of distance to direct their goal pursuit efforts and later monitor this distance to track their progress until the goal is reached or satisfied. This mechanism appears simple yet provides an overarching explanation for a complex set of regulatory functions. Earlier research in social psychology by Miller (1944) and Lewin (1951) also had identified the role of psychological distance in approach/avoidance, psychological conflicts, and various elements of human behaviour. However, the current state of research has not put the same emphasis on the role of psychological distance in understanding and explaining self-regulation, despite having direct and broader implications that could connect a wide range of related phenomena and theories with each other, and despite innovative interventions for self-regulation improvement that are implied.

Psychological distance, implicitly or explicitly, has been a common construct among many

seemingly unrelated topics and phenomena. Several brief yet important points about the construct and its role in various self-regulation topics are noted below to show the significance of the construct, and then implications of using it for understanding and improving self-regulation are discussed.

Distance Perception and Self-Regulatory Processes

Distance Perception and Control Theory

The approach/avoidance system in control theory has been a major model for explaining overall self-regulation processes (Carver, 2006; Carver & Scheier, 1998). It discusses *monitoring* and *implementation* as main phases and mechanisms of goal pursuit, and accordingly focuses on the concept of distance as a main factor in monitoring the discrepancy between individuals and their goals. These goal-discrepancies could be identified and pursued at different levels, for example, in higher-level goals such as changing a personality trait or self-image (e.g., being an environmentally conscious person), or lower-level goals such as performing an action (e.g., separating recyclables from trash). It is noteworthy that, although the hierarchal nature of goal pursuit system has been discussed in the literature (Scholer & Higgins, 2013, 2015) and considered originally in control theory (Carver & Scheier, 1982), it is not yet fully explored.

Psychological Distance and Psychological Connectedness

One of the original definitions of psychological distance by Sigel (1982), a developmental psychologist, discusses psychological distancing as a "representational competency" for children in their developmental progress to cognitively separate themselves from present (i.e.,

present here and now) objects or situations[2], which highlights a deeper relationship between psychological distance and psychological connectedness (i.e., a process to understand the self as separated from other entities in an environment such as people or objects). Self-expansion models also suggest that individuals include or separate other people, objects, or groups in the self-concept or vice versa (Aron et al., 1992; Belk, 1988), which indicates that people use a very similar process that, for example, impact how psychologically close or distant they feel to others.

In addition, there is a wide range of studies regarding psychological connectedness to past or future (i.e., events related to temporally different situations and versions of the self, e.g., future self), and its effect on intertemporal choices (Bartels & Rips, 2010; Urminsky, 2017). Some researchers have attempted to show the possibility of improving self-regulation by increasing connectedness to the future. For example, using an interactive design to experience the future-self through virtual reality has been shown to increase future self-continuity and impact participants' ability to delay gratification (Hershfield et al., 2011; van Gelder et al., 2013), as indicated by their performance in delay tasks and retirement-saving tasks. Also, relevant marketing research has shown that providing simulations of future life situations with computer technologies impacts decision making and can change product preference (Urban et al., 1997; also see: Goldstein et al., 2015). Similar studies also discuss how, for example, feeling psychologically closer to a self-concept such as vividness of future self can affect intertemporal choices, which is a fundamental factor in the delay of gratification mechanism (van Gelder et al., 2013).

Overall, we can discuss psychological distance and psychological connectedness as concepts that could translate into one another. Despite the underlying relationship between these

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[2] This present environment has also been called an "immediate" environment (Sigel, 1982)

constructs, they have been largely studied separately.

As mentioned earlier, people identify discrepancies between themselves and their goals, which motivates them to move towards their goal to reduce these discrepancies. Accordingly, researchers can also identify mechanisms that individuals use to feel closer (or further) from an object, person, group, or identity, for example, by including them in their perception of the self (i.e., inclusion of others, or objects in the self, e.g., see Aron et al., 1992; Belk, 1988) to increase or decrease emotional or social distance, for example, towards a tempting situation or object. This shows how the concept of psychological distance relates to a wide range of phenomena that study psychological connectedness and creates further opportunities by using both constructs simultaneously for increasing psychological connectedness and distance to help individuals battle temptations and make better decisions.

Psychological Distance and Basic Self-Control Processes

In addition to the processes involved in self-regulation more generally, basic self-control strategies such as *distraction* and *abstraction* in delay of gratification (Mischel et al., 1989) can be explained using psychological distance language (Mischel & Rodriguez, 1993). When discussing the delay of gratification paradigm, the major challenge is removing the motivational pull of temptations that create a strong motivation by immersing one's self in the immediate environment (i.e., creating a narrow attention and strong motivation towards a salient target such as a tasty candy).

Distraction and abstraction have been identified as effective methods to battle these temptations (Mischel et al., 1989), as discussed in previous chapters. We can use the language of psychological distance to explain the efficacy of these methods and provide a richer understanding of the experiential aspects of the situation. One can create psychological distance through distraction, which shifts a person's attention towards another aspect of the

environment. This helps an individual distance themselves from a tempting situation and feel less immersed in the situation that involves continuing self-control conflict and temptation (Mischel & Rodriguez, 1993). It is also possible to create psychological distance through abstraction, which creates alternative mental representations of the situation. In other words, the individual reconstrues or reappraises the immediate situation, and therefore the tempting features of the environment (Mischel & Rodriguez, 1993).

Psychological Distance and Emotion or Desire Regulation—In this thesis, self-control is defined as a conflict or dilemma resulting from the presence of dual or multiple conflicting motivations. I mostly investigate and discuss conflicts that occur in situations involving interfering motivations or desires that have strong psychological pulls, such as when we encounter strong unwanted desires of a palatable food. Using the language of psychological distance allows us to more accurately understand self-control by distinguishing between more and less healthy self-control strategies. We can identify two different strategies of addressing a conflict: (1) resisting the pull of a conflicting motivation to delay gratification, or (2) resolving the conflict, which usually involves reconstruing how we think about the situation. This distinction is equivalent to studies that explore the difference between more and less healthy methods of overriding an unwanted emotion (i.e., in the emotion regulation literature). Overriding an unwanted emotional state can be accomplished by (1) suppressing the unwanted emotion, or (2) regulating the emotion through reappraising the situation (Gross, 1998).

Similarly, we can think about desire regulation through two self-control strategies. First, we can resist a temptation while keeping it psychologically close to the self, which creates a high degree of psychological conflict because the close and consequently strong conflicting motivation is not getting resolved. For example, we can resist eating a tempting dessert while continuing to think about how tasty eating it would be. On the other hand, we can resolve this conflict through methods that makes the tempting food more psychologically distant so

that it has less strain on the mind, thus decreasing the strength of the temptation. Reconstruing how we think about a tempting snack, for example, by distraction or abstraction methods in delay of gratification research (Metcalfe & Mischel, 1999; Mischel et al., 1989) can help us regulate the unwanted desire. For example, we can associate one choice with negative health consequences and unpleasant self-images or create more psychological distance between ourselves and the source of temptation (e.g., putting the snacks away in closed cabinets or the basement where it is not easily reachable). Effectively resolving self-control conflicts could include psychologically distancing the source of negative motivation while also asymmetrically shifting motivational strength and value of conflicting goals or choice at the same time (Fishbach & Converse, 2010; Fujita & Sasota, 2011; Myrseth et al., 2009)—that is, strengthening the positive motivation while simultaneously weakening the negative interfering motivation. For example, when we need to study and want to resist the temptation of spending more time on social media via a smartphone, we might just try to put the phone away to distance the source of interfering motivation. At the same time, we can strengthen our motivation to study by thinking about positive feelings and outcomes of academic success at the end of the term (i.e., increasing its perceived value and motivational strength). In other words, asymmetrical shifts of motivations consist of bringing the source of positive motivation psychologically closer while pushing the source of the interfering and conflicting motivation further away.

This new point of view and language can unify a broader scope of topics and phenomena about self-regulation improvement and help us better identify more positive and healthy approaches for designing interaction techniques and technologies for self-regulation improvement.

Psychological Distance and Implications for Interactive Technologies

The points discussed above underline how we can use the concept of psychological distance to gain a novel understanding of self-regulation and self-regulation improvement mechanisms. Two additional points that give significance to using psychological distance is the malleability of our distance perceptions, especially when considering how we mainly use our perceptual system, specifically visual percepts and images, to change psychological distance. These factors indicate the importance of using technologies that provide us with vastly more options to mediate or change people's visual perception or impact their mental imagery for helping them battle temptations and regulate their behaviour.

Malleability of Distance Perception

More recent findings regarding the approach/avoidance system highlight the subjectivity and malleability of psychological distance from a goal or temptation (Alter & Balcetis, 2011; Balcetis, 2014; Balcetis & Dunning, 2010; Cole, Balcetis, & Dunning, 2013; Cole, Balcetis, & Zhang, 2013). An important aspect of these findings is the effect of hedonic experiences (e.g., when facing a temptation item or situation) on distance perception (Balcetis, 2014) and how malleability of these perceptions might play a role in motivational systems that counteract these temptations. These findings especially call further attention to considering the role of perceived psychological distance in how tempting objects or situations are, and how we can similarly increase distance to avoid or overcome hedonic experiences that are major factors in self-regulation failure in many domains such as eating behaviour (Loewenstein, 1996; Mann et al., 2007).

Perceptual System and Psychological Distance

Dichotomy of Changes in Psychological Distance—More recent theories of psychological distance, such as construal level theory (CLT), have developed models that directly relate level of

construal (i.e., abstraction level) to psychological distance. Such models put great emphasis on conceptual systems at the centre of determining the distance between the self and an object or event that involves mental construals to understand and evaluate objects or events. This conceptualization contradicts the established understanding of psychological distance development (Sigel, 1982). The concept of psychological distance is based in experience (i.e., feeling close to or far away from an object or situation), which primarily relies on visual imagery and percepts (Pashko, 2016). It therefore is directly related to the perceptual system, including visual perceptions and mental imagery, and only then translates into *concepts* to make sense of these images through a conceptual system such as language (Pashko, 2016). CLT has also depicted a somewhat linear relationship between construal level and psychological distance, which assumes psychological distance gradually changes as we increase abstraction (however, see: Maglio et al., 2013). This assumption largely ignores the mechanisms of the perceptual system for increasing and decreasing psychological distance, which could be exploited to improve the self-regulation of behaviour. We can distance ourselves from an immediate situation that we no longer want to feel immersed in. This could refer to changing our physical presence in a situation or reappraising the immediate situation[3]. For example, when a person is facing a tempting cake, or is immersed in mental imagery of that desirable food item, they experience the temptation of the cake in the immediate situation. However, this temptation can be countered by various distancing strategies, for example, distracting themselves in order to change the immediate environment. This shift from immersed to distanced states suggests a more dichotomous nature to changes of psychological distance.

[3] The concept of immediate situation or immediate environment does not refer to the physical space in an environment, but the space that a person mentally construes between the self, the goal, and various regions of possible activities between them (Lewin, 1951), which is extremely useful to describe the experiential aspects in a goal pursuit situation.

For instance, Kross, Ayduk & Mischel (2005) also showed the possibility of adopting a third-person perspective that allows participants to quickly distance themselves from immersive thoughts that cause re-living the memory of an unpleasant event. In addition, a person also feels psychologically closer towards their goal in a situation when they are immersed in it (Balcetis, 2014; Cole et al., 2014). For instance, a person who is motivated to reach a finish line in a competition feels psychologically closer to the finish line when running towards the target as they immerse in the situation (Cole et al., 2014).

Changing Psychological Distance

The contribution of this chapter included providing a critical review of research about the concept of psychological distance, which highlights its significance as a central factor to consider when designing for improving the self-regulation of desire and behaviour.

This review highlighted the role of psychological distance as a central factor in self-regulation processes and self-regulation success, and its significance in understanding experiential aspects of people's challenges in pursuing their goals when facing temptations and conflicting motivations.

A major role that interactive technologies can play then is intervening in people's perceptual systems to help them to distance themselves from situations more effectively, for example, by more abstractly perceiving a situation by exploring various visual techniques that could increase the distance of an object or situation.

These techniques are mostly unexplored and could greatly facilitate distancing unwanted desires when individuals are immersed in a tempting and challenging situation and could ultimately assist successful self-regulation. Therefore, exploring the use of various psychological distance dimensions for designing and testing methods that could help individuals battle unwanted desires is the main focus of the following chapters. Chapter 7 explores the

possibility of increasing perceived temporal distance using a simple framing technique with a focus on underlying theories that support the idea. Chapter 8 explores using a simple interaction technique by using saturation and framing techniques to distance desires and resist temptations of appealing foods. Chapter 9 uses these techniques and a distancing mechanism in a longitudinal setting to practice self-regulation of desire and behaviour.

Chapter 7
The Effect of Framing on Perceived Psychological Distance and Abstraction

In this chapter, I investigate the possibility of changing how a person perceives an object or event by using simple interaction techniques of *framing* a photo of an object, activity or event. We can use various techniques to psychologically distance ourselves from the content of a picture as discussed in the previous chapter. One option is exploring methods that could change the temporal distance of an image, for example, thinking about a food item as being disconnected or distant from the present, which could reduce its motivational pull. Therefore, I conducted an online experimental study to investigate the effectiveness of this approach on people's perception of temporal distance and abstraction level as important factors of effective self-regulation.

Study 3: The Effect of Framing Photos on Perceived Psychological Distance and Abstraction

I adopt the technique of *framing* used in the Marshmallow test (Mischel et al., 1972, 1989), which helped children think more abstractly about a challenging situation and distance themselves from a tempting snack by creating a frame with their hands through which they looked at the tempting snack. The researchers argued that the children who used this technique created more abstract and distant perceptions of the tempting object and could therefore more effectively delay their gratification. In Study 3, I explore using an actual frame around a picture to investigate whether we can ultimately use this technique to change how we perceive a photo, and thus potentially use it as a self-regulation method. Notably, physical and digital frames are used to preserve the memory of images and events that have

happened in the past. Imposing a frame around a picture could associate the content of a frame with past events or memories, thus distancing the object from the immediate present. Therefore, I explored the method of increasing psychological distance by increasing the *temporal distance* of a picture in an online experiment.

Even though this interaction technique does not necessarily require computer technologies, investigating this effect through computer technologies could have additional important benefits. Using interventions that have applications for media technologies is an important factor in designing and testing digital versions of interaction techniques to help people resist temptations, which might especially impact people with lower levels of self-regulation who can struggle to resist temptation (Hofmann, Baumeister, et al., 2012). This may be especially true for people who are more prone to mentally ruminating on intrusive thoughts more broadly (Kavanagh et al., 2005; May et al., 2012, 2015). Social media can make it difficult for individuals who have a challenging relationship with food, as posting images of foods—images that are specifically captured to make the food look desirable—has recently become highly pervasive (Abbar et al., 2015). While technology has created new ways of spreading temptations that can make it difficult to resist unwanted desires, it can also provide novel methods and techniques to regulate those desires by increasing our psychological distance from them.

In this study, I test the method of increasing psychological distance by increasing the *temporal distance* of a picture, which could potentially be used to reduce the temptation of desirable foods.

Method

I conducted an experiment to investigate the effect of seeing a photo through a frame with the purpose of investigating the impact of framing a photo on how distant the object in the

photo feels, and how abstractly people think about the content of the photo. Previous research in CLT suggests a direct relationship between how abstractly we construe a past or future event and its perceived psychological distance (Yaacov Trope & Liberman, 2010), suggesting that abstraction level and psychological distance variables directly impact and determine one another. Therefore, I test the effect of framing a photo on both how *distant* and how *abstract* the photographed object is perceived by participants in the study.

Participants

216 participants (95 identified as female, 120 identified as male, 1 not specified) were recruited from Amazon Mechanical Turk (MTurk) based on the recommendations of Simmons et al. (2013) for these online platforms. Participants were instructed to complete a short survey in a study about perception for a $1 monetary reward. 5.5% of participants identified as having Asian background, 6.9% as African-American, 81.0% as Caucasian, 3.7% as Hispanic, 0.46% as Middle-Eastern, 0.46% as Native Americans, and 1.4% as having other backgrounds. 0.46% of participants also chose not to report.

Procedure

The experiment involved showing a series of photos to participants. Participants were randomly assigned to one of two conditions, one that involved seeing only framed photos (*framed photos* group) and the other that involved seeing identical photos with no frame (*non-framed photos* group). Participants went through six photos and answered several questions about each photo regarding its level of abstraction, subjective distance, capture date distance, perceived importance and their attitude towards the photo. Specifically, the measures used in the study are as follows:

Level of abstraction—Participants were first asked to identify the action that was taking place

in the photo (i.e., action identification task) to determine how abstractly they thought about each photo. The research in CLT has used this action identification task, also called the Behaviour Identification Form (BIF) (Vallacher & Wegner, 1987, 1989), in many experiments to measure changes in the level of abstraction or facilitate manipulating abstraction level (Fujita, Henderson, et al., 2006; Liberman & Trope, 1998). This task was originally designed as a scale to measure a person's overall trait or state level of abstraction by using a series of actions as items of the scale and asking participants to identify an action by one of two provided descriptions, one of which describes *how* the action was performed (i.e., concrete aspects of the action) and the other that describes *why* the action was performed (i.e., abstract aspects of the action). The main criteria for choosing items from the BIF to use for the photo stimuli in this study were: (1) Would it make sense for a person to frame the photo? For example, paying rent is one of the actions from the BIF items; however, a person would not likely frame a photo of themselves paying rent. The photos that were chosen for the study were of items from the BIF that were most likely to be framed. (2) Could the action be captured in such a way that would make the photo describable in both concrete and abstraction terms? The photos were shown in counterbalanced order, and the order of the two options for each question remained the same as in the original scale.

The actual photo stimuli are shown in Figure 11. The behaviours depicted in the photos were as follows: a) "toothbrushing," which could be construed more abstractly as "preventing tooth decay" or more concretely as "moving a brush around in one's mouth," (b) "climbing a tree," which could be construed more concretely as "holding on to branches" or more abstractly as "getting a good view," (c) "painting a room," which could be construed more concretely as "applying brush strokes" or more abstractly as "making the room look fresh," (d) "reading," which could be construed more concretely as "following lines of print" or more abstractly as "gaining knowledge," (e) "greeting someone," which could be construed more concretely as "saying hello" or more abstractly as "showing friendliness," and (f) "voting," which could be

construed more concretely as “putting the vote in the ballot box” or more abstractly as “influencing the election”.

Distance—Participants then were asked “How close or far away does the moment depicted in this photo feel?” using a scale from 1 (Feels very far away) to 10 (Feels very close) that was reverse-scored to measure their subjective distance. They were then asked “How long ago do you think this photo was taken?” using a scale from 1 (Feels like a long time ago) to 10 (Feels like yesterday) that was also reverse-scored to measure their perceived “capture date” distance, that is, their perceived distance from the date that the photos were taken.

Importance and Attitude—Participants then were asked “How important do you think this moment was?” using a scale from 1 (Not at all important) to 7 (Extremely important) to measure perceived importance of the photos, and “How much do you like this photo?” using a scale from 1 (Not at all) to 7 (Extremely) to measure their overall attitude towards the photos.

Other Questions—After participants went through all the photos, they answered questions about the devices they used, the distance and size of the device, and the Internet browser size they used (that they were asked to maximize for the duration of the study). They then answered a series of demographic questions, and two attention-check questions including “How closely did you pay attention to the instructions of the study?” and “To what extent did you take the study seriously when answering the questions?” while being assured that these answers would not affect their payment.

Figure 11. Examples of photos that were used in the study to represent selected behaviour from action identification task.[4]

[4] The attributions for the three photos included in this graph are as follows: (1) reading: a royalty-free photo in *Shutterstock*, ID: 383682277, (2) voting: the photo is modified and shared under creative commons licence 2.0 generic, creator ID: *kelvinhu* at *Flickr,* link: *https://tinyurl.com/4set9vy9*. (3) climbing a tree: the photo is modified and shared under creative commons licence, creator ID: *wonderlane*, link: *https://tinyurl.com/4n3rp7m4*. For more information about all the photos used in this study, please see the additional materials link: https://osf.io/pyd36/?view_only=665b86f57c4f4cbdbdbeed48747aaad4

Pre-registered Procedures and Hypotheses

The procedure, data analyses and hypotheses were pre-registered using *Aspredicted.org*. The pre-registration form is included in the link for the supplementary materials. The following hypotheses were pre-registered based on the procedure that was mentioned previously:

H1: Participants in the *framed photos* group will perceive the photos to be more distant than participants in the *non-framed* photos group.

H2: Participants in the *framed photos* group will think about the photos more abstractly than participants in the *non-framed* photos group.

H3: Participants in the *framed photos* group will think of the photos as more important than participants in the *non-framed* photos group.

Inclusion Criteria—Two inclusion criteria were applied. As mentioned, participants were asked about the level of attention they invested in the study. The time that they spend in the study was measured, and 3 minutes was set as a minimum duration for including participants in the main analysis.

Results

Pre-registered Inclusion Criteria—While all participants passed the attention questions, 19 participants were excluded from the main analyses because they spent less than 3 minutes to complete all questions. Therefore, from 216 participants, 197 participants (87 identified as female, 109 identified as male, 1 not specified) passed all inclusion criteria. I have therefore conducted the main analysis on those 197 datapoints and only included additional exploratory analysis with the full dataset to further compare the two study conditions.

Pre-registered Analyses

The primary tests of interest were t-tests comparing average scores of distance, abstraction, and importance between conditions (framed vs. unframed).

Distance

I ran two independent *t*-tests to compare responses regarding perceived subjective and capture date distance between the *framed photos* and *non-framed photos* groups. The results of these analyses showed trends in the predicted direction (a slightly higher level of perceived subjective distance in the frame condition than the unframed condition), but no significant differences. Specifically, there was no significant difference between the *framed photos* and *non-framed photos* groups on subjective distance, t_{195}= 1.25, p = .21 (*framed photos*: M = 4.9, SD = 1.48, *non-framed photos*: M = 4.64, SD = 1.36; Cohen's d = .18), or capture distance, t_{195}= 1.01, p = .31 (*framed photos*: M = 4.82, SD = 1.39, *non-framed photos*: M = 4.63, SD = 1.28; Cohen's d = .14).

Exploratory Additional analyses—Originally, the exclusion criteria were formulated with the assumption that answering the questions too quickly would indicate that participants were not paying attention to the study. However, given that all participants passed the attention check (and that MTurk participants tend to complete surveys faster than other potential participants such as university samples, e.g., see: Hauser et al., 2019; Wood et al., 2017), I explored the same analyses reported above while including all participants. I again used independent *t*-tests to compare responses regarding perceived subjective distance and capture date distance between the *framed photos* and *non-framed photos* groups. When including the full participant sample, a significant difference emerged between the *framed photos* and *non-framed photos* groups for subjective distance, t_{214}= 2.08, p = .039 (*framed photos*: M = 5.04, SD = 1.60, *non-framed photos*: M = 4.63, SD = 1.35; Cohen's d = .28). However, the difference between conditions on capture date distance remained non-significant, t_{214}= 1.54, p = .12 (*framed photos*: M = 4.92, SD = 1.42, *non-framed photos*: M = 4.64, SD = 1.25; Cohen's d = .21). The difference

between the results when analysing the full sample and analysis of the subset of participants who spent more than 3 minutes on the study could be attributed to how pronounced the differences in distance perception were for the group of 19 participants who completed the experiment more quickly (i.e., in less than 3 minutes), t_{17}= 2.79, p = .015 (*framed photos*: M = 6.63, SD = 2.04, *non-framed photos*: M = 4.43, SD = 1.25; Cohen's d = 1.32).

Abstraction:

I ran an independent t-test to compare abstraction level in participants' responses to the action-identification questions between the *framed photos* and *non-framed photos* groups. The results of this analysis showed no significant difference between the two groups, t_{195}= -.96, p = .34 (*framed photos*: M = 1.57, SD = .32, *non-framed photos*: M = 1.62, SD = .28; Cohen's d = -.17); contrary to predictions, this analysis even showed a slightly lower abstraction level for the *framed photos* group.

Additional Exploratory Analysis— Similarly, when including all 216 participants, the result indicated no significant difference between *framed photos* and *non-framed photos* groups, t_{214}= -1.30, p = .19 (*framed photos*: M = 1.57, SD = .33, *non-framed photos*: M = 1.62, SD = .28; Cohen's d = -.16).

Perceived Importance

I ran two independent t-tests to compare the perceived importance of the photos and participants' attitudes towards the photos between the *framed photos* and *non-framed photos* groups. The results of the first analysis showed a difference in the predicted direction between the two groups regarding how important they perceive the photos to be, t_{195}= -1.66, p = .099 (*framed photos*: M = 3.68, SD = 1.02, *non-framed photos*: M = 3.94, SD = 1.14; Cohen's d = -.24) although did not reach a significant level. The results of the second analysis showed no significant difference between participants' attitudes towards the photos in the *framed photos* and *non-framed photos* groups, even though participants' attitudes overall were slightly less

positive towards the framed photos t_{195}= -1.38, p = .17 (*framed photos*: M = 3.82, SD = 1.2, *non-framed photos*: M = 4.05, SD = 1.13; Cohen's d = -.20).

Exploratory Analysis

Correlational Analysis—The result of testing differences between the responses from the *framed photos* and *non-framed photos* groups shows a contradictory pattern for the main theoretical assumptions (drawn from CLT) that were used to generate the hypotheses in this study, that is, the relationship between psychological distance and construal level. Therefore, I conducted additional correlational analyses to investigate the relationship between measures of distance, abstraction, importance, and attitude (see Table 5).

The results of these analyses showed a negative relationship, although not significant, between level of abstraction and perceived subjective distance (N = 197, r = -.13 p = .072), and a significant negative relationship between abstraction and capture date distance (N = 197, r = -.14 p = .043). The results also showed a positive relationship between the level of abstraction and perceived importance of photos (N = 197, r = .22, p = .0022), and between level of abstraction and attitudes towards the photos (N = 197, r = .27 p = .00009). On the contrary, the results showed a negative relationship between the level of subjective distance and perceived importance of the photos (N = 197, r = -.41, p < .00001), and between level of subjective distance and attitudes towards the photos (N = 197, r = -.55, p < .00001). Similarly, the results showed a negative relationship between the level of capture date distance and perceived importance of photos (N = 197, r = -.31, p < .00001), and between the level of capture date distance and attitudes towards the photos (N = 197, r = -.47, p < .00001).

As expected, the results of correlational analysis showed a very strong correlation between measures of capture date and subjective distance (N = 197, r = .85 p < .00001) and between

measures of perceived importance of photos and attitude towards the photos (N = 197, r = .76, p < .00001).

Table 5.
Relationship between variables: Pearson Correlation Coefficients

	Psychological Distance	Psychological Distance (Date)	Importance	Attitude
Abstraction	**-0.13†** **(.072)**	**-0.14*** **(.043)**	**.22**** **(.0022)**	**0.27***** **(<.0001)**
Psychological Distance	.-	**0.85***** **(<.0001)**	**-0.41 ***** **(<.0001)**	**-0.55***** **(<.0001)**
Psychological Distance (Date)	-	-	**-0.31***** **(<.0001)**	**-0.47 ***** **(<.0001)**
Importance	-	-		**0.76***** **(<.00001)**

Significant levels are the result of Pearson correlation test. N= 197, ***p<.001, **p<.01, *p<.05, †p<.1

Discussion

The framed photos were rated slightly higher in terms of their perceived distance; however, the results of the study did not indicate a considerable difference between the level of perceived distance when framing photos. The results also showed no significant difference between the level of abstraction when comparing the two conditions. This is particularly noteworthy because the perceived abstraction of framed photos was not significantly different from non-framed photos and the means were not in the predicted direction, which presents a contradictory pattern to what was hypothesized and more importantly to its underlying assumptions, that is, a parallel pattern between level of abstraction and psychological distance (Trope & Liberman, 2010; also see: Kyung et al., 2014) that highlight recent issues

regarding these assumptions.

The results also showed that, contrary to predictions, participants found framed photos to be slightly less important. One possible explanation is that participants regard older photos as less important, which is also supported by the strong correlations between distance and importance measures or distance or attitude measures. An alternative explanation for differences in the importance ratings could be the effect of expectation violations, that is, people expect a photo to be very important when they decide to frame it, and therefore judge a framed photo to be less important when they see a framed photo whose content does not meet their expectations. Overall, these relationships indicate that using this method could create unexpected effects that work against what is anticipated. These patterns therefore need further investigation to understand how perceived importance of a photo can be dependent on its perceived capture date and its contents.

In addition, the results of the correlational analyses indicate a negative relationship between abstraction and psychological distance as measured by both perceptions of capture date distance and subjective distance. This result is in direct contradiction with the theoretical assumptions of CLT that informed my hypotheses. I should also note that researchers have attempted to replicate some of findings related to CLT (e.g., see: Calderon et al., 2020; Gong & Medin., 2012; Žeželj & Jokić, 2014), and these attempted replications have produced mixed results that do not always support the findings of the original articles (also see: Kyung, Menon & Trope., 2014). Notably, CLT is depicted and presented as a major and comprehensive framework in psychological science (Yaacov Trope & Liberman, 2010), but has not yet been subject to rigorous replication attempts and critical discussion regarding its primary theoretical contributions.

There are a few important points that need consideration when designing similar studies. In my choice of photos, I tried to only use photos that are frameable, in a sense that people

would find them believable as framed photos. Also, the decision to only use photos that corresponded to behaviours described in the action-identification scale limited our choices of photo stimuli as well. Therefore, it may be valuable for future research to explore a conceptual replication of this study in order to test the result of the study in different contexts that do not necessarily require using the exact actions described in the BIF. In addition, running the study in an online setting creates specific challenges, such as lacking a controlled setting to ensure participants pay enough attention to the instructions of the study. Another thing that researchers need to consider is that one challenge in creating the stimuli used in this study is that the photos needed to be made as realistic as possible to resemble a physical frame. Although none of the participants mentioned that the frames looked unrealistic, the challenge of choosing the right frame to fit the photos and make the stimuli look realistic needs to be acknowledged.

Conclusion

Overall, the findings of this study point out some interesting conclusions that could potentially be drawn from this work. However, even by an optimistic interpretation, the effect sizes created by this manipulation were small. Therefore, using this exact framing technique for design purposes in order to benefit the general population might not be appropriate without further investigation. The inconclusive nature of these findings also calls for further investigation of the theoretical claims in the CLT literature. Notably, this study highlights the need to pay more attention to a lack of clarity or possible shortcomings in overarching theories of self-regulation and their sometimes simplistic descriptions of complex relationships, such as the relationship between psychological distance and temporally present or past mental construals. Lastly, future work should also consider other possible avenues of manipulating perceptions of temporal distance, especially by harnessing the potential of interactive technologies.

In this chapter, I explored using simple interaction techniques to change the temporal distance that a person feels towards the content of a photo such as an activity or event (in this case, a food item). The goal of the study presented in this chapter was to rely on theoretical frameworks in the research to design interaction techniques that could be used on tempting photos of desirable foods. In the next chapter, I will investigate using other interaction techniques such as *framing* and *saturation* that more directly impact people's perception to help them effectively distance and resist tempting foods.

The contributions of this chapter included providing empirical evidence on using a simple design technique to impact people's perception of temporal distance and level of abstraction (Study 3) that revealed only a slight change in perceived temporal distance and no difference in level of abstraction. These findings were also notably contradictory to what is presented by construal-level theory on the relationship between abstraction and psychological distance.

Chapter 8
Using Interactive Technologies to Battle Temptations

Human-Computer Interaction (HCI) research has focused mostly on using interactive technologies to facilitate healthy eating behaviour by tracking users' goal progress or increasing users' motivation to pursue their health-related goals (for a review, see: Lyngs et al., 2019; Pinder et al., 2018) with no focus on the impact of hedonic experiences of tempting foods. The idea of using what people visually perceive as a self-control help tool has been previously explored in some HCI research, for instance, by making distracting non-work tabs in a web browser less prominent than work tabs (Lottridge et al., 2012), or designing interactions that explore how using images of various healthy and unhealthy foods can affect people's attitude towards them through evaluative conditioning (Pinder et al., 2016). Here I will test how such ideas can be used as an interaction technique to help people resist and regulate the strong desires they experience by tempting foods.

Study 4: Resisting Tempting Foods with Image Filters: The Effects of Saturation and Framing on Hedonic Experiences

In this chapter, I describe the design of an experimental study with 153 participants who identified as women to investigate the effect of simple technology-mediated changes such as seeing a food through the frame of a mobile device and black-and-white (versus coloured) imagery. The goal was to test whether changing how a person visually perceives a rewarding stimulus could affect temptation and the strength of their desire for that stimulus, as well as their behaviour. This approach can inform how we use interactive technologies to ultimately

create intervention techniques that can alter people's visual perception and in turn help them regulate their unwanted desires and pursue their health-related goals. With emerging wearable technologies, such as regular and mixed-reality smart-glasses, real-time practices that directly affect people's perceptual systems are becoming more and more practical and could lead to larger impacts on people's lives. The results, while most generalizable to women (see section 3.1.2), suggest that a grayscale filter is effective at reducing attraction, strong desire, and temptation to eat more unhealthy snacks, but that the framing of mobile devices is not. These findings highlight that using technology to impact people's health-related daily experiences is promising.

Figure 12. In this study, I explored the effect of seeing a tempting food through the frame of a camera using grayscale image filters.

Attenuating Temptation

In this study, I investigated whether using technology can create a less tempting representation of a food to help people regulate their unwanted desires. I based the study design on

two relevant lines of research related to how modulating visual perception influences our experiences and decision-making processes.

Studies have shown that black-and-white images of an object result in attending to more abstract features of an item such as its shape, rather than its concrete features such as its colour, and consequently influence people's purchasing decisions (Hyojin Lee et al., 2014). Also, black-and-white imagery of events is shown to be associated with feeling more temporally distant by thinking about more abstract features of the event (Hyojin Lee et al., 2017). Attending to concrete vs. more contextualized features of an item is an important factor when encountering a tempting item, because the concrete features are often the features that are related to consumption of the item. The stronger appeal of a coloured image of a food when compared to a filtered black-and-white version might seem obvious, for example, when we see a shared photo of palatable and tasty foods on social media; however, it is not clear if the effect would translate to a situation in which we are looking at a real-time camera preview of the food vs. a black-and-white or coloured version through a camera. In this study, I examined the effect of a black-and-white filter on reducing how tempted and attracted people felt toward the food.

In another line of work, Mischel et al. (1972; 1989) have also explored techniques that help people attend less to tempting features of a stimuli, for example, by reconstruing how pre-school children would think about a tasty marshmallow (e.g., picturing it as a cloud) or by simply using both hands to create a hypothetical frame to look at the food through. This research demonstrates that this technique can help someone to attend to the larger context of the situation and think about a tempting stimulus, such as a marshmallow, more abstractly. Therefore, I wanted to test whether seeing a food through the frame of a mobile device's camera could likewise create an effective technique for distancing the tempting stimuli. However, I acknowledge that given little information about how the pre-school children used the framing technique in those studies, it is not clear both methods are

comparable. For instance, the angular size of the object (also called the visual angle) can easily change when I see an object in a camera. This could neutralize the expected effect or even *reduce* the perceived distance of an object (i.e., increasing the size-perception of a tempting stimuli).

Method

I conducted an experimental study to investigate if mediating a person's visual perception using camera filters or through the frames of a camera would affect people's experience and behaviour when facing a readily available unhealthy snack (M&M's). Figure 13 shows the three conditions used in the study in a between-participants design. In two conditions, participants used an iPad tablet to mediate what they visually perceived, by either using a coloured camera preview (*colour condition*), or a grayscale view (*grayscale condition*) of the food. The third condition had no tablet (*no-tablet condition*) and participants could see the food directly.

Hypotheses

I had the following hypotheses:

Participants in the *grayscale tablet* condition would (H1.1) experience less attraction toward M&M's, weaker desire for the M&M's, and less temptation or conflict to eat more, and (H1.2) eat a smaller number of M&M's than in the *colour tablet* condition.

Participants in both the *grayscale* and *colour tablet* conditions would (H2.1) experience less attraction toward M&M's, weaker desire for the M&M's, and less temptation or conflict to eat more, and (H2.2) eat a smaller number of M&M's than in the *no-tablet* condition.

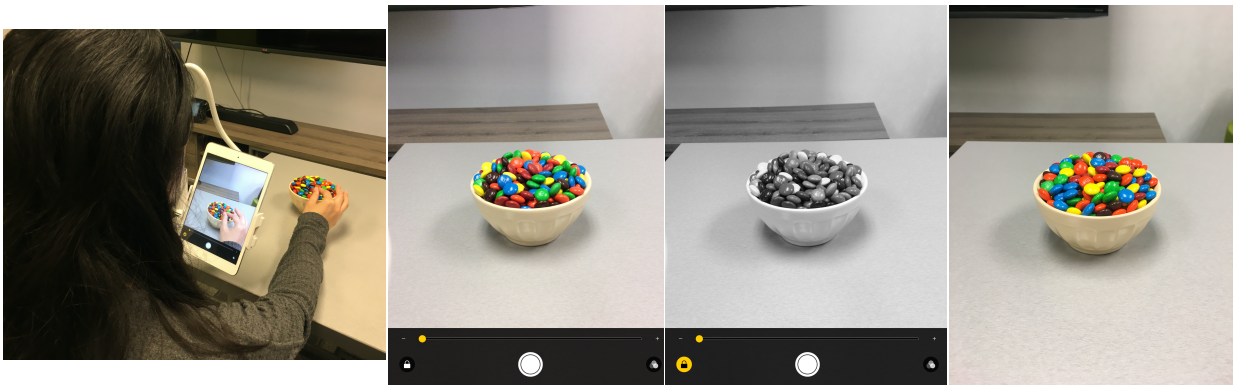


Figure 13. The pictures above, from left to right respectively, show (a) the study setting when having a tablet in the condition, (b) a screenshot of the tablet in colour condition, (c) a screenshot of the tablet in the grayscale condition, and (d) a picture of the viewpoint in the no-tablet condition (Note that the pictures do not necessarily replicate how a person experiences M&Ms in the study).

Participants

One hundred and fifty-three women (M_{age} = 20.7, SD_{age} = 2.85) were recruited through campus flyers to participate in a "Taste Perception Study" for $10. I aimed to recruit 150 people to complete the full study in order to have at least 50 people in each condition, following the recommendation of Simmons et al. (2013). Two individuals went through the survey part of the study, but were not comfortable eating the M&M's, so did not continue, but were fully compensated for filling out the final survey. One individual also did not comply with the study instruction of using the iPad and removed the M&Ms outside the boundaries of the iPad. These three participants were not included in the analyses. I chose chocolate M&M's as snacks that could be attractive to a considerable number of potential participants, and I advertised the study as such by using posters with the product's picture to attract those who enjoy eating M&M's. 47.0% of participants identified as having Asian background, 2.0% as African-American, 27.5% as Caucasian, 1.3% as Hispanic, 2.6% as Middle-Eastern, 8.5% as Indian, and 10.5% as having other backgrounds. 0.65% of participants also chose not to report.

Following other work that has studied eating behaviour, I recruited only participants that

identified as women, since they are statistically known to have more dieting concerns than men (Fujita & Carnevale, 2012; Fujita & Han, 2009). It was important that the participants had dieting concerns, but I could not advertise the importance of this factor in recruitment materials because of concerns with revealing study hypotheses to participants. I used the Revised Restraint Eating Scale (Heatherton et al., 1988) to identify chronic dieters who have restrained eating tendencies and dieting concerns using a cut-off point of 16 or higher (Adams et al., 2019; Heatherton, 1993; Polivy & Herman, 1999; Roefs et al., 2005). The assumption was that these participants would experience a desire to restrain themselves from eating too many M&M's. A recent study (N = 1684) showed that women scored significantly higher (M=13.63, SD=5.95, ~66th percentile=16.0) than men (M=10.27, SD=5.20, ~87th percentile=16.0) in restraint eating scores, especially in younger populations in which men have lower and women have higher dieting concerns (Adams et al., 2019). Thus, I would need to have recruited around 2.5 times as many men as women to achieve the goal of recruiting 150 participants. In this sample, 140 of 150 participants (93%) scored 16 or higher on the Revised Restraint Scale, which is not surprising, given the targeted recruitment material and the age distribution (Mean age = 20.7) of the participants who were younger (Adams et al., 2019). The recruitment criteria were primarily motivated by the desire to reduce noise in the data and to simplify the recruitment procedure. Recruiting only women made it more likely that the sample would be suitable and helped the validity of the results, even though it limits the findings' generalizability.

To be clear, not all women are concerned about dieting, and not all men are unconcerned about dieting, and I make no such claims. Rather, this recruitment technique was targeted based on known statistics similar too our local community to maximize the likelihood that participants would experience a self-control conflict. I should also clarify that experiencing a self-control conflict is not the same as having poor self-control in that domain (in this case, eating behaviour). Everyone experiences self-control conflicts, and that can be healthy.

Rather, I want to communicate that women were overall more likely to have dieting concerns, and therefore when faced with a food like M&Ms, more likely to experience a temptation and conflict between the desire to eat them and concern for their health and health-related goals (i.e., a self-control conflict), regardless of how they resolved that conflict and whether they resisted the food (i.e., self-control level and competency). On the other hand, when someone unconcerned with dieting is faced with M&Ms, they would not have a self-control conflict (independent of how many they eat) and would not be a suitable participant.

Procedure

Participants were randomly assigned to one of three conditions that were counterbalanced to ensure participants in different conditions were equally assigned at various times of the day. After arriving at the lab, participants were welcomed and introduced to a study about investigating the effect of different visual settings or visual effects on how people taste and review a product, the M&M's snack. After going through the instructions about the details of the task, they were left alone in the lab for 15 minutes to rate the product on 5 aspects (i.e., tastiness, naturalness, sweetness, healthiness, and visual attractiveness), and write an open-ended review about the product while they were sitting in front of the snack. The experimenter then returned to the room after exactly 15 minutes. Participants were then asked to answer some questions about their experience during the tasks. Later, they moved to the next room to fill out a questionnaire.

Measures

Behavioural Measure—I measured snack intake by the weight of M&M's each participant had during the taste-and-rate task. To measure the amount of M&M's, I weighed the bowl before and after the task, using a scale with a precision of 0.1g. To ensure the bowl of M&M's looked similar to participants between conditions, its weight was kept as consistent as possible at the beginning of the task at approximately 560g (M = 560.3g, SD = 2.2g). The weight includes the

214g weight of the bowl.

Self-Report Measures—I also asked participants to answer questions regarding several important aspects of self-control. Participants were asked to select to what extent they agreed or disagreed with a series of statements using a 7-point scale from 1 (strongly disagree) to 7 (strongly agree). The statements were about experiencing attraction toward the snack ("I found M&M's to be attractive at the moment"), strong desire ("I experienced strong desires toward M&M's"), temptation to eat more ("While rating M&M's, I felt tempted to eat more"), and an item about experiencing conflict by thinking they are eating more than needed ("I felt conflicted about eating more M&M's than I need to"). These items were inspired by the measures used in other self-regulation studies (Hofmann, Baumeister, et al., 2012; Milyavskaya et al., 2015; Milyavskaya & Inzlicht, 2016). I also asked individuals to report how easy it was not to eat more ("I found it difficult to control myself not to eat more M&M's"), which is an important factor on how people regulate their behaviour (Milyavskaya et al., 2015) and how bored they were during the task ("I was bored during the taste-and-rate task") as another factor that can influence people's behaviour.

Questionnaires—The survey part of the study had a variety of questions including a series of questions about how hungry participants were, what time they had their last meal, how frequently they snack in general and specifically how frequently they eat M&M's to help control for possible confounds. I also asked participants about their attitude about M&M's to ensure that my advertisement strategies were effective and my sample population liked M&M's. Note that I asked these questions post-experiment to minimize their effect on primary behavioural and self-report measures. I then used several validated scales, including the Behavioural Identification Form (Vallacher & Wegner, 1989) and Self-Control Scale (Tangney et al., 2004b) to investigate possible effects of trait level differences in self-control and abstraction level on the results of the behavioural and self-report measures. I used the Restraint Eating Scale (Herman & Polivy, 1980) to investigate if participants had dieting concerns and

were considered chronic dieters (i.e., had restraint eating tendencies), since such tendencies are associated with different perceptions and patterns of behaviour related to food. I also asked about binge-eating tendencies using the following items: “I binge-eat a lot.”; “Once I start eating a tasty snack, it is very hard for me to stop.”; “I can stop eating when I think I have had enough.”; “I usually keep snacking until I feel stuffed.”; “I sometimes cannot stop eating until I feel disgusted.” The wording of some of the items were inspired by Gormally et al.’s (1982) assessment of binge-eating behaviour.

Results

I performed a one-way analysis of variance (ANOVA) to test the hypotheses regarding the effect of condition on self-regulation-related variables. Among all measures, food intake was the only variable that was skewed (*Skewness* = 1.74, *Kurtosis*= 3.64), for which I used a natural log-transformation.

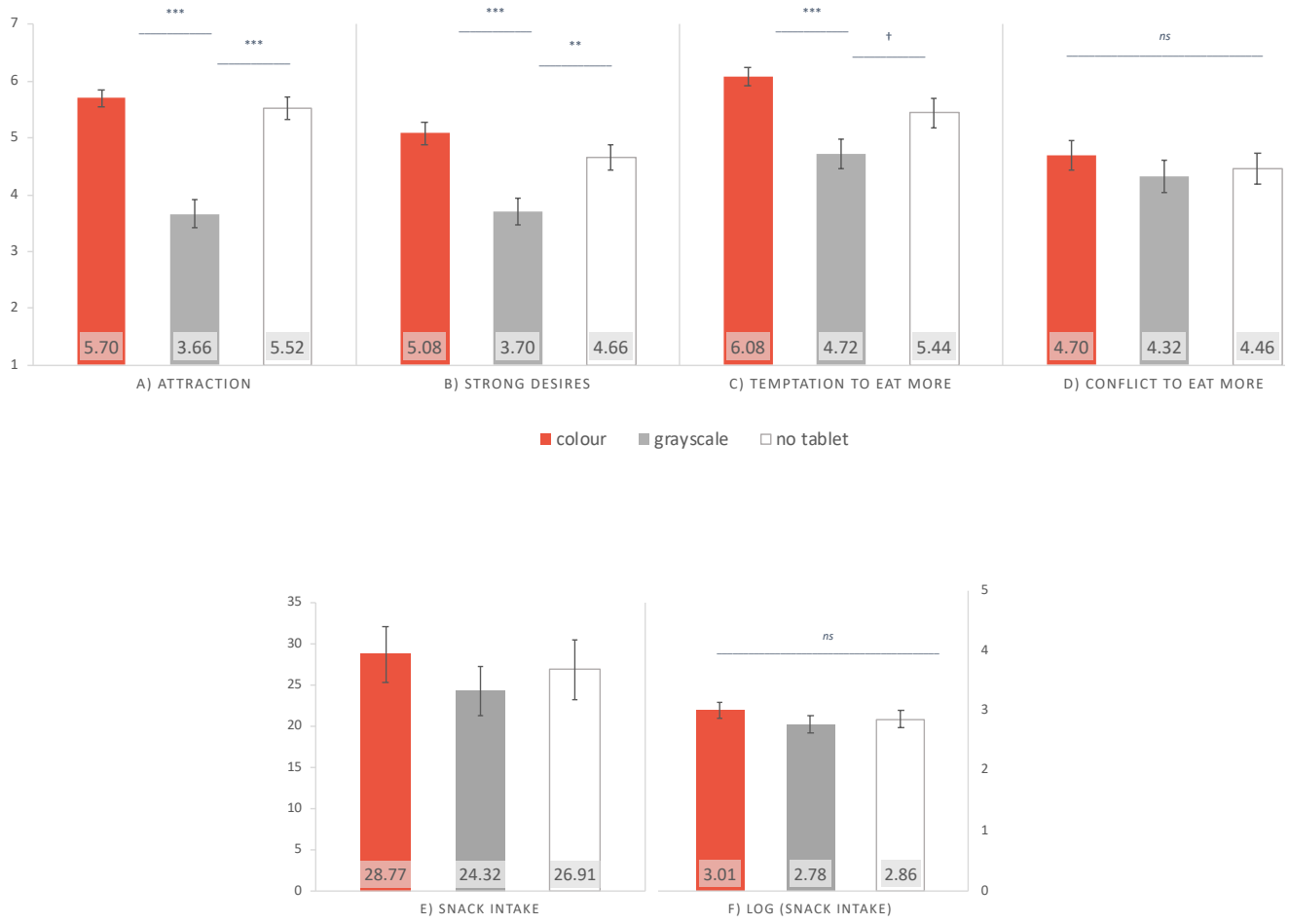


Figure 14. Participants' experience of (a) attraction, (b) strong desires towards M&M snacks and (c) temptation and (d) psychological conflict to eat more during the experiment. Error bars represent ±1 standard error of the mean. Significant levels are the result of Bonferroni-corrected post hoc comparisons. *N* = 150, ***p<.001, **p<.001, *p<.01, †p<.1

Behavioural Measure

I conducted a one-way ANOVA using log-transformed values of food intake as a dependent variable and mediation technique (colour, grayscale, no tablet) as the factor. The number of M&M's each participant had during the taste-and-rate task was slightly lower in the *grayscale*

condition than the *colour* and *no-tablet* conditions (original values: M_{colour} = 28.7g , SD_{colour} = 23.9g; $M_{grayscale}$ = 24.3g , $SD_{grayscale}$ = 21.6g ; $M_{nothing}$ = 26.9g , $SD_{nothing}$ = 25.3g, Figure 14.e), though not significantly, $F_{2,147}$ = 0.724, p = .49 (log-transformed values: M_{colour} = 3.01, SD_{colour} = 0.89; $M_{grayscale}$ = 2.78 , $SD_{grayscale}$ = 1.02 ; $M_{nothing}$ = 2.86 , $SD_{nothing}$ = 1.02, Figure 14.f). I asked participants about possible reasons that motivated them to eat more or fewer M&M's during the fifteen minutes of the task. Four participants mentioned eating more or fewer M&M's for external reasons. A few participants thought they might be judged if they ate more and a few mentioned they pushed themselves to eat more because they thought they were expected to. However, I included all one hundred and fifty participants in the analyses. Note that the reported result of the food intake remains the same without including those participants. None of the participants suspected that I would actually measure the weight or number of M&M's that were eaten.

Self-Report Measures

I also ran several one-way ANOVAs on participants' experience of attraction toward, strong desire for, temptation to eat more, and conflict to eat more M&M's as dependent variables and condition as the factor. These additional analyses are presented in Figure 14. The result of these analyses indicates that there were significant differences between conditions on how attracted participants felt toward the snacks, $F_{2,147}$ = 31.23, p < .00001, η^2 = .298 (M_{colour} = 5.70, SD_{colour} = 1.09; $M_{grayscale}$ = 3.66, $SD_{grayscale}$ = 1.76; $M_{no\text{-}tablet}$ = 5.52, $SD_{no\text{-}tablet}$ = 1.36, Figure 14..a), the strength of participants' desire for the M&M's, $F_{2,147}$ = 10.35, p < .00001, η^2 = .123 (M_{colour} = 5.08, SD_{colour} = 1.32; $M_{grayscale}$ = 3.70, $SD_{grayscale}$ = 1.71; $M_{no\text{-}tablet}$ = 4.66, $SD_{no\text{-}tablet}$ = 1.61, Figure 14.b), and participants' temptation to eat more, $F_{2,147}$ = 8.60, p = .00030, η^2 = .104 (M_{colour} = 6.08, SD_{colour} = 1.18; $M_{grayscale}$ = 4.72, $SD_{grayscale}$ = 1.85; $M_{no\text{-}tablet}$ = 5.44, $SD_{no\text{-}tablet}$ = 1.81, Figure 14.c), but no significant difference in experiencing conflict to eat more, $F_{2,147}$ = 0.50, p = .61 (M_{colour} = 4.70, SD_{colour} = 1.89; $M_{grayscale}$ = 4.32, $SD_{grayscale}$ = 1.99; $M_{no\text{-}tablet}$ = 4.46, $SD_{no\text{-}tablet}$ = 1.91, Figure 14.d.)

I subsequently conducted Bonferroni-adjusted post-hoc analyses (see significance-level lines in Figure 14). Results show that participants in the *grayscale* condition experienced less attraction toward the snack than in the *colour* condition $MD_{grayscale,colour}$ = -2.04 (i.e., mean difference), $p < .00001$, d = 1.43, 95% CI = [.94,1.91] and the *no-tablet* condition, $MD_{grayscale,no\text{-}tablet}$ = -1.86, $p < .00001$, d = 1.30, 95% CI = [.82,1.79]. However, the difference in people's attraction to the food between the *colour* and *no-tablet* condition was not significant, $MD_{colour,no\text{-}tablet}$ = 0.18, p = 1.0 (Figure 14.a). The analyses for experiencing strong desires shows that participants in the *colour* condition reported experiencing stronger desire than people in the *grayscale* condition $MD_{grayscale,colour}$ = -1.28 p = .00005, d = 0.89, 95% CI = [0.40,1.37], and the *no-tablet* condition, $MD_{grayscale,no\text{-}tablet}$ = -0.96, p = .0073, d = 0.62, 95% CI = [0.13,1.10]. People in the *colour* condition experienced slightly stronger desire (though not significantly) for the snack than in the *no-tablet* condition, $MD_{colour,no\text{-}tablet}$ = 0.42, p =.54 (Figure 14.b). Similarly, the post-hoc analyses on experience of temptation indicates that participants in the *grayscale* condition reported experiencing significantly lower temptation to eat more snacks than in the *colour* condition $MD_{grayscale,colour}$ = -1.36 p = .00017, d = 0.83, 95% CI = [0.34,1.31], and more than in the *no-tablet* condition, $MD_{grayscale,no\text{-}tablet}$ = -0.72, p = .090, d = 0.44, 95% CI = [-0.05,0.92], although not showed a significant level. People in the *colour* condition experienced slightly more temptation (though not significantly) to eat more than in the *no-tablet* condition, $MD_{colour,no\text{-}tablet}$ = 0.64, p =.16 (Figure 14.b).

Additional Analyses

I measured participants' Restraint Eating scores to identify whether they were chronic dieters. One hundred and forty participants scored above 16 on the Restraint Scale. I performed the one-way ANOVAs only for those participants that scored high on restraint eating tendencies, who thus had higher dieting concerns, and the result of these analyses were identical to the previous results. I also measured participants' positive attitude toward M&M's post-

experiment to ensure the advertisement mostly attracted people who were actually interested in eating M&M's. Ninety-eight participants reported to have a medium to strong positive attitude toward M&M's. I therefore performed one-way ANOVAs only for participants with strongly positive attitudes toward M&M's, the primary target population of the study. The results of these analyses were the same: there were significant differences between conditions on how attracted participants felt toward the snacks, $F_{2,95} = 33.31$, $p < .00001$, desire for the snacks, $F_{2,95} = 10.06$, $p = .00011$, and temptation to eat more, $F_{2,92} = 11.54$, $p < .00001$, but no significant difference in conflict to eat more, $F_{2,95} = 0.17$, $p = .84$.

The one-way ANOVA indicated that there was a significant difference in reported level of binge-eating between conditions, $F_{2,147} = 4.46$, $p = .013$ ($M_{colour} = 4.10$, $SD_{colour} = 1.08$; $M_{grayscale} = 3.95$, $SD_{grayscale} = .90$; $M_{no\text{-}tablet} = 4.53$, $SD_{no\text{-}tablet} = 1.02$). There were no significant differences between conditions on how frequently participants snacked, $F_{2,147} = 1.74$, $p = .18$, and how frequently they had M&M's, $F_{2,147} = 0.24$, $p = .79$. As mentioned before, I originally collected data regarding positive attitudes toward M&M's to ensure the recruited participants actually liked M&M's. However, there was also a difference between the conditions in their post-experiment attitudes toward M&M's, $F_{2,147} = 2.41$, $p = .093$ ($M_{colour} = 3.20$, $SD_{colour} = 1.01$; $M_{grayscale} = 2.76$, $SD_{grayscale} = .96$; $M_{no\text{-}tablet} = 3.04$, $SD_{no\text{-}tablet} = 1.07$) although did not reach significance. Even though it is quite likely that the variables were affected by participants' experience during the taste-and-rate task, I repeated the main analyses using binge-eating and attitude toward M&M's as covariates in the model, which creates a very conservative comparison of conditions. The pattern of the one-way ANOVA results also is identical and the post-hoc analysis of group comparisons reveals the same level of significance for all self-report variables.

I also performed additional analyses to further investigate the relationship between the self-report measures and the behavioural measure. Pearson correlations indicated that snack intake (using the log-transformed values) was correlated with level of attraction toward M&M's ($N = 150$, $r = .35$, $p < .00001$), experiencing strong desires toward M&M's ($N = 150$, $r =$

.43, $p < .00001$), temptation to eat more M&M's ($N = 150$, $r = .50$, $p < .00001$), and the level of conflict participants experienced to eat more M&M's ($N = 150$, $r = .30$, $p < .00001$), which shows a relationship between the self-report measures and behavioural measure.

Discussion

The main findings of this study were:

- Using grayscale image filters in a mobile device resulted in less attraction to and desire for M&M's, and less temptation to eat more M&M's.
- Looking at tempting food only through the frames of the camera without the grayscale filter, however, did not have the same effect.
- The pattern of results is robust even when controlling for binge-eating tendency and positive attitudes toward M&M's.

The findings of this study can inform other work in HCI that uses technology to help people resist tempting foods and, more broadly, regulate a range of similar unwanted desires that their visually appealing feature have great motivational pulls on individuals. Specifically, it shows the promising aspect of visualization techniques to change how a person perceives a situation or stimulus. For example, simply exploring other image filters (e.g., cooling/warming effects) could result in more insights regarding techniques to use technology to mitigate temptations. More broadly, researchers can investigate visualisation techniques that help people reconstrue an item, for example, by creating an unrealistic or modified version of a food.

Our study shows that simply using image filters could help people feel less attracted to and experience less strong desire for a tasty snack, but seeing a picture through the frame of a mobile device does not result in a *framing effect* that effectively allowed someone to think more abstractly about the food and change the psychological distance of a tempting food, as

has been found in other work (Mischel, 1974; Mischel et al., 1989). It may be that the original framing effect is dependent on the size-perception of tempting stimuli and attributable to the visual angle of the object, but this would require further analysis.

Participants' comments and feedback after the study reinforced the findings. Many participants in the *grayscale* condition mentioned that M&M's surprisingly did not look as appealing as they used to. A few participants more specifically pointed out that M&M's were not as attractive even though they could remember colourful M&M's that they used to eat and how appealing they were. A few participants in the *colour* condition also mentioned perceiving the colour of M&M's as more vibrant than they expected, even though no image filters were used. This could explain the small differences in results between the *colour* and *no-tablet* conditions. As I mentioned in the previous section, I asked participants about possible reasons that motivated them to eat more or fewer M&M's during the fifteen-minute task. A number of participants also pointed out that they had in mind a certain number of M&M's that they wanted to eat before coming to the study. Having a pre-determined decision might be a reason for the non-significant results I found for the behavioural measure, even though participants reported significant differences in self-report measures of attraction, strong desire and temptation, and, notably, the level of attraction, desire and temptation was significantly correlated with how many snacks they had during the taste-and-rate task. An alternative possibility is that the study might not have been statistically powered enough to detect smaller effect sizes for investigating changes in snack intake given the high variability of the snack intake variable in the data.

A large number of participants hinted at the importance of colour on how they perceived the M&M's, its appeal throughout the years and developing habits or preferences for different M&M's colours. This notion is also highlighted in other studies in food science and psychological science research of the effect of colour on choices and preference, or arousal (e.g., see: Clydesdale, 1993; Walsh et al., 1990; Walters et al., 1982). This was an important factor in

this study and was a reason for choosing a visually appealing snack as the tempting food. In this study, I specifically focused on how mediating visual perception by using image filters can help people feel less tempted toward those foods.

I explored mitigating the tempting aspects of a food using a mobile device. Even though one could consider the modification I have used in these study conditions as augmented reality, I encourage others to use more advanced augmented reality techniques for the same purpose. For instance, using devices such as the Microsoft HoloLens could expand the capability to make changes to what people are directly seeing through the headset, and may therefore greatly strengthen the effect of such interventions.

Conclusion

I designed an experimental study to investigate the effect of seeing a tempting food through black-and-white image filters and a frame of a camera. Participants experienced less attraction towards unhealthy snacks and their experience of temptation and desire during a taste-and-rate task in the experiment. These results demonstrate that using simple technological interventions to change how a person experiences a situation can help mitigate unwanted desires and temptations. The study specifically highlights the effect of using image filters on how a person visually perceives a tempting food and presents empirical evidence that should encourage researchers to explore a similar approach using technologies that can impact how people visually perceive tempting items and situations.

The contributions of this chapter included providing empirical evidence regarding testing interaction techniques to battle temptation of visually desirable food items through simple image filters that could be used with commonly accessible technologies and integrated with more advanced technologies. The evidence shows the effectiveness of saturation techniques in helping people experience less temptation and unwanted desires by visually mediating

what they experienced. These techniques inform researchers of simple technological interventions that help people distance tempting food objects.

Chapter 9
Designing Interactive Technologies for Self-Regulation Improvement

The results of Study 4 are promising regarding using simple techniques that could be applied through accessible technologies, such as mobile phones, for regulating unwanted desires and behaviour when encountering a tempting food item.

As previously mentioned, the lack of technological designs for desire-regulation highlights that there is limited focus on the challenges that people experience in a self-regulation conflict situation and there is limited knowledge regarding how we can intervene to address the troubling aspects of a visually appealing temptation using interactive technologies.

Study 5: Resisting Tempting Foods Using Interactive Methods: a longitudinal study

In a continuation of Study 4's investigation, I integrated the hot/cool self-regulation technique (i.e., using the saturation feature to cool down or heat up specific photos) with physical distancing (i.e., making the images of photos smaller and larger) to create a stronger yet simple interaction technique that could be used in a mobile application.

In this chapter, I focus on the design, implementation, and testing of this interactive self-regulatory strategy in a longitudinal intervention study. This study allowed me to test whether people might benefit from practicing these kinds of self-regulation strategies in a more realistic setting.

Practicing Self-Regulation

A major challenge in designing interventions for self-regulation improvement is that the situations in which we learn strategies or practice mental operations for self-regulation are often different from the situations in which they need to be applied. For example, in an actual self-control conflict, stronger temptation makes it more difficult to change our mental representations to a more abstract level and attend to more goal-relevant environmental cues or mental thoughts (e.g., see: Fujita & Carnevale, 2012). Relatedly, activation of tempting thoughts can negatively impact our working memory, which is essential for exercising self-control (Hofmann et al., 2011) and elaborating on the future. Therefore, there is a gap between the experience of exercising self-regulation in a hypothetical situation and a situation that involves actually experiencing strong and unwanted desires. Similarly, there is a gap between what we learn, and how effectively we are able to apply what we have learned, when we practice self-regulation in these two different situations.

This distinction corresponds to the difference between 'learning self-regulation' as declarative and procedural knowledge that could result in a competency to regulate our desires and behaviours (Gollwitzer, 1999; Smith, 1994). Therefore, successful self-regulation possibly can be achieved through practicing these strategies and their corresponding mental operations in situations that trigger actual self-control dilemmas.

For that reason, practicing mental operations in interactive experiences that resemble the complexity of situations can help implement strategies by linking action phases to specific situations ('knowing when') and integrating the strategies and mental operations learned ('knowing how') into those complex situations.

Successful self-regulation relies on knowing "when" and "how" to implement self-control (Myrseth & Fishbach, 2009b) in a given situation, which includes identifying a conflict and successfully implementing self-regulation strategies (Smith, 1994). Also, people are sometimes aware of the effect of situations on them, especially for resisting strong temptations.

They are aware of the importance of some self-regulatory strategies, such as thinking about future outcomes related to each choice, but they still often fail to employ the strategies at the right moment. This shows that simply knowing about self-regulation strategies does not guarantee success. Some people who experience numerous self-control conflicts may have also experienced multiple failures (e.g., those who look for self-imposed punishments or rewards as pre-commitment strategies). People can anticipate the difficulty of upcoming temptations. However, they mostly still set their goals and intentions when considering hypothetical, non-conflict situations rather than reflecting on the challenges of a self-control situation and have limited opportunity to practice self-regulatory strategies in more realistic situations, that is, less intense self-control situations that still resemble facing a temptation or self-control conflict.

Ultimately, the characterization of self-regulation strategies as procedural knowledge (i.e., know-how), rather than declarative (i.e., know-what), emphasizes the necessity of creating interactive environments in which to practice, learn this knowledge, and improve self-regulation competency. In addition, significant changes in motivation states and how people evaluate conflicting motivations could be the result of the type of self-regulation practice that involves *actually* exercising self-control (Fishbach et al., 2010; Fishbach & Myrseth, 2010; Myrseth et al., 2009).

Therefore, interactive experiences can be most effective if the environment that we practice self-regulation in resembles a self-control dilemma situation (e.g., experiencing tempting options when using an interface) and mental operations that we practice resemble the mental operations found in real life (e.g., characteristics of the interface and interaction techniques resemble our visual perception). Interactive technologies are an excellent option for providing such an environment.

In this work, I will investigate the process of designing an interactive experience that allows

participants to experience temptations somewhat similarly to how they experience them in real life so that users can practice self-regulation in the designed setting.

Design

I first discuss the design aspects of the technology I designed and implemented. I decided to integrate the simple interaction technique used in Study 4, to create a mobile application that could be used to practice regulating desires and behaviours for real-life situations outside a lab setting, that is, a mobile application that allows people to use the same interaction techniques on the food-items of their choice using the app.

In order to practice self-regulation in a realistic setting, we can design technology to help people in real-life situations (i.e., when self-regulation conflicts and temptations of a food appear in everyday life) or create situations that resemble conflicting situations (i.e., situations that involve similar factors, such as temptations).

I explored multiple design prototypes before implementing the full prototype that is presented in this chapter. The design process of the app also involved a few iterations of low- and high-fidelity prototypes in order to create a design that is both functional and satisfactory.

In my experience of designing and testing the prototype, there were several factors that needed attention and adjustment. These design considerations are derived from several design iterations along with evolving research questions and study methods, which together allowed me to better understand the issues and requirements of designing such an application (Gaver, 2012; Zimmerman et al., 2007). The goal of this process was to implement these interaction techniques in a longitudinal experiment that could ultimately be similar in functionality to an actual product used in a real-world application.

In the design process, I found that there were a few main design considerations that significantly impact how we approach this challenge that are discussed in the following sections:

Real-time vs. non-real-time practice

As previously mentioned, designing an assistive technology and intervention can have two approaches: 1) creating a design that can assist people to help them regulate unwanted desires when they face temptations during the day, for instance, when they are shopping for foods, or when someone is at home and a tempting bowl of cookies looms large in their eyes, or (2) creating a design that simulates features of a real-world experience, for example, a challenging situation of experiencing strong temptation, which allows them to have an environment to practice them separately.

To create a self-assisting technology, we need to consider if the design would be beneficial for people *when* or *where* it is required. We can create something that works for real-time battling of temptations and practicing self-regulation, which would require people to take a picture of or preview a tempting food and their device would, for example, cool it down (i.e., turn the picture into a *visually* cooler, and thus less tempting, version of the food). I encountered a few issues when attempting to integrate this idea into a prototype. Specifically, while being an effective interaction technique, it might not work as a practical intervention self-assisting technological tool. For instance, when an individual is tempted with a desirable and palatable food, the items could be inaccessible until they are actually purchased and brought home or ordered in a restaurant. Therefore, the real-time application could backfire because people may have already made a decision to indulge in the temptation before they could use the app. At that point, cooling the temptation down would have little effect.

Personalized Gallery

Non-real-time practice, therefore, is important for providing practice *before* getting into a tempting or conflicting situation. However, there are potential issues that arise when designing this type of application as well.

To give participants a platform for using the designed interaction techniques (e.g., hot/cool and distancing features), a few options were explored. One option was having participants capture the photos of the foods that they want to practice regulating. A second option was to provide them with a library of photos that they could choose from. In other words, we can create for them a premade food library from which they can choose the photos that resemble what they eat or drink regularly in order to build a personalized gallery, or we can ask them to create this personalized gallery from scratch by taking new photos using their own mobile devices to capture all the photos.

The advantage of having participants capture their own photos is that a participant's choice of photos could make the food more personally relatable. However, the disadvantage of this option is that participants need to spend a significant amount of time capturing the photos that they want to use for the intervention period. In order to integrate this design element with a longitudinal study, it would require having at least several days of a gallery-building phase through which participants can take photos of food items that they encounter during those days. This approach creates significant barriers for the quality of the collected data for the study as participants are influenced by their experience of this phase, which could add to the length and complexity of the study design and thus lower compliance. In addition, one specific downside is that in the gallery-building phase, participants could indulge in behaviours that lead to self-regulation failure and therefore might impact their experience and behaviour in the coming weeks as well. Also, people have different levels of expertise and different techniques for capturing photos. Thus, the quality, size and consistency of photos participants would capture themselves would vary greatly, thus impacting the appeal of engaging with the app, or the effectiveness of the visual self-regulation techniques.

Using a pre-made gallery, on the other hand, could potentially limit the extent to which a participant feels related to the images provided to them. Also, creating a gallery that includes photos for all groups of people with specific diets, lifestyle, or creating a gallery that encompasses food items for all cultures proves to be very challenging.

I chose to build a food library for participants to use for building a personalized gallery by considering the trade-offs mentioned above, that made the second option more appealing and appropriate for a one-to-two-week longitudinal study. Creating a food library provided more consistency to the study as all participants can choose a considerable number of photos with consistently good quality. This is particularly important for this study as I intend to use the photos to simulate the experience of temptation for self-regulation practice, and for participants to perform a few interaction techniques that help resist and regulate temptations. Having a food library also significantly reduces the complexity of the study procedure by using a simple setting that could impact both the quality of data and the compliance with the study.

Food Library Design

A food diary consisting of more than two hundred images of a variety of food items were provided to participants. Figure 15 shows a grid view of all the food items chosen to be included in the library. The food library needed to be adjusted based on the potential participants in the study. The photos were chosen through a process of: (1) building an initial food library, (2) creating a list of food categories using the input of several lab members, and then (3) adjusting the food library based on the created lists to provide a somewhat comprehensive food library, especially for participants in North America that were the most likely to participate in the study.

Even though participants were not provided with food categories and were not asked to

balance their choices across the categories, I arranged the food library in a way that similar foods (i.e., those that are likely to be in the same category, e.g., various pizzas or pastries) would be in closer proximity to each other so that participants have an easier time selecting among possible options as they see all options next to each other, for example, when they want to choose a cake image.

Even though the choices in the food option are items that are more common in western countries, this study has not focused on studying the best way to categorize foods items or create a gallery. I included all photos that were used in this section since the study procedure refrained from using labels such as names and categories for the study.

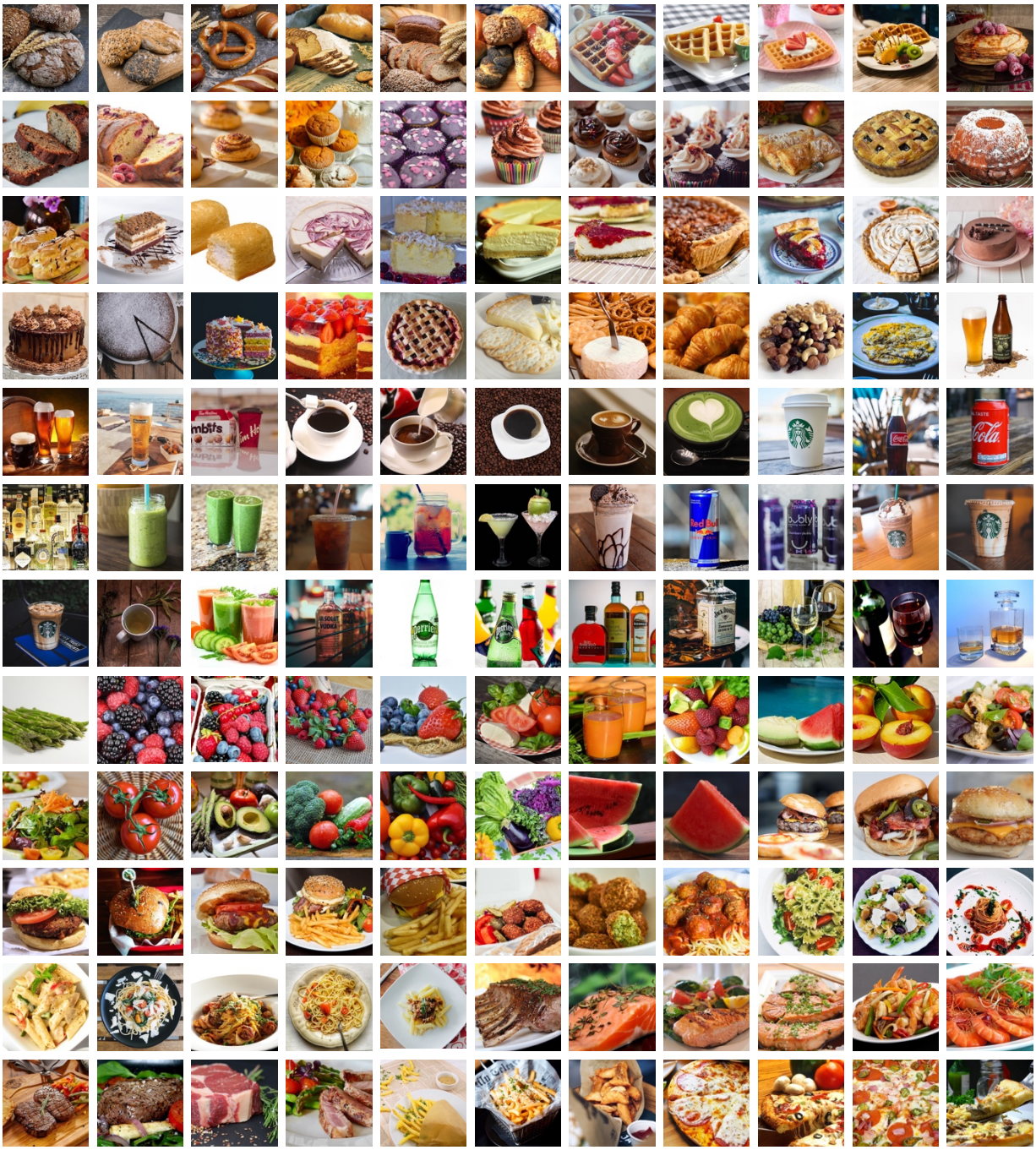
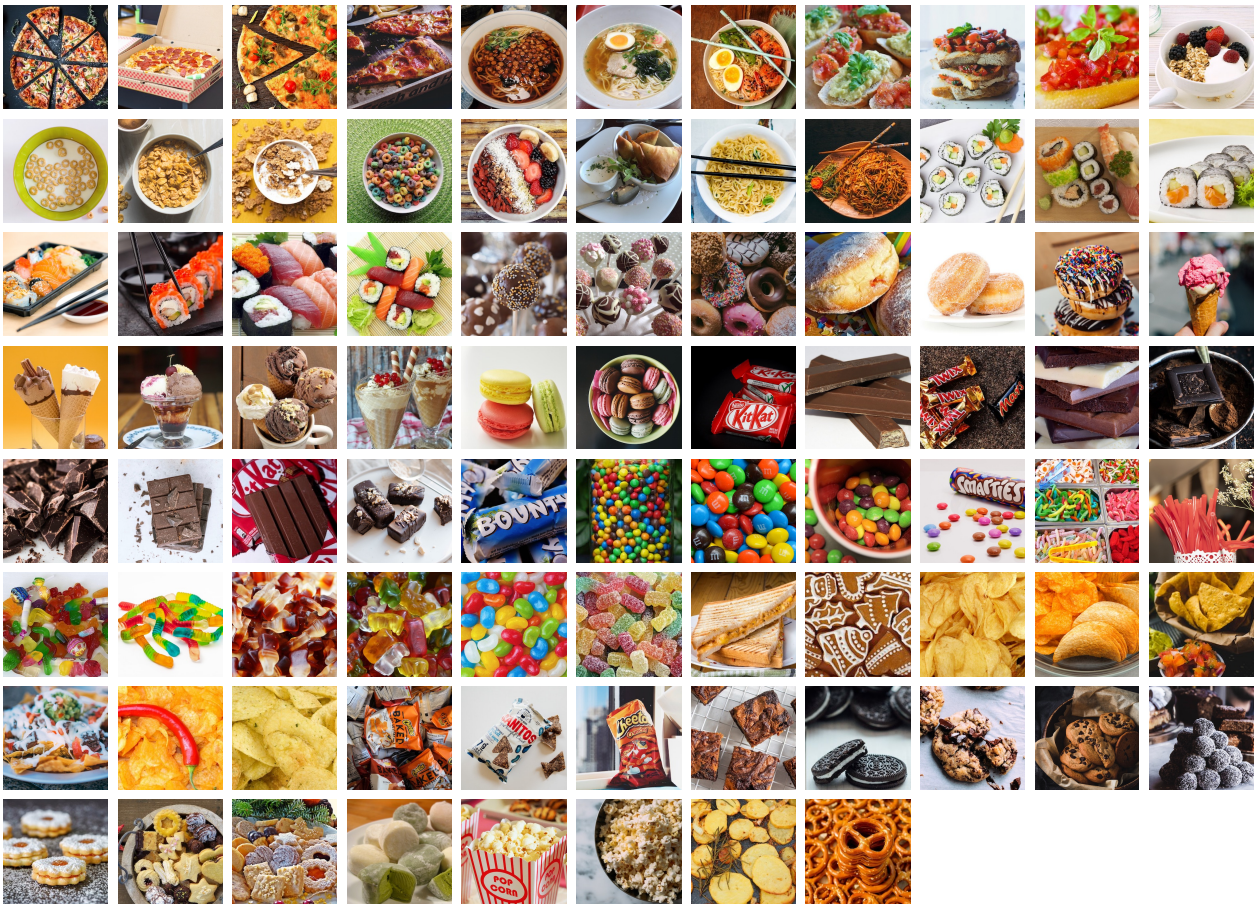


Figure 15. A grid-view of all photos included in the pre-made food library that participants could choose from. (the figure is continued in the next pages.)



(cont.) Figure 15. A grid-view of all photos included in the food library for participants could choose from.

App Design

I used the Unity 2019.2.9f1 game engine to design and test final prototype and develop the app for publishing on Android and iOS phones. The application is designed for people who want to make changes to their eating behaviour. In this application, people can first provide information regarding these changes by selecting the photos that they wanted to eat more or less of. I included the *hot* feature in the app as well to test it in the app and provide a balance for the people who want to both increase and decrease the appeal of the foods they

eat.

The app comprises three main pages (see Figure 16). The application includes a gallery page that participants can use to view which photos they have chosen from the food library that is provided for them, and they have the option to also return to the food library to add or review photos in their personalized galleries at any time (Figure 16). It also includes a practice page for designing a review-exercise, in which a person who uses the app could review the chosen photos and evaluate them and swipe them right or left by pushing the yes or no button. People can use this feature daily once or multiple times to review the choices they want to make for the day (i.e., setting their specific goals for the day to strengthen their motivation and intention for achieving those goals by reflecting on their goals and values while evaluating them). They can also use the app as many times as they need to later in day.

Both versions of the app allow people to use this practice page to go through all the photos in their personalized gallery to review the choices that they want to make in the daily exercise. They could make decisions and evaluate the photos by using yes or no buttons to swipe the photos to the right or left. One version of the app also includes the hot and cool buttons and distancing features that were previously discussed. People who use the hot/cool version of the app have the option to make the photos visually less or more appealing through

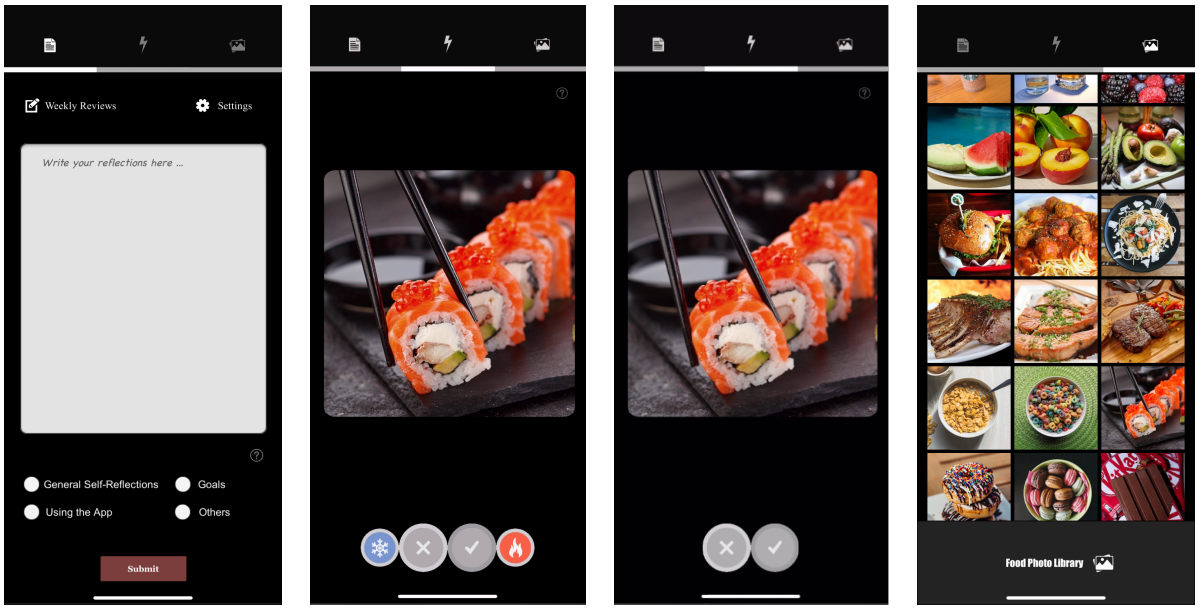


Figure 16. the main pages of the app, from left to right, are the Reflection page, a sample Practice page for hot/cool version of the app, sample Practice page for yet/no version of the app, and a sample personalized Gallery page. The second picture from the left show hot and cool buttons of the app, that lets the individual make the photo more or less tempting. The yes/no button in the middle swipe the photos to right and left respectively.

changing their level of saturation and size, that is, distancing the photos (see Figure 16 and Figure 17). Therefore, there were two version of the app, (1) a yes/no version that allows people to do a review exercise using yes/no buttons to evaluate their choices and swipe the photos left and right, and (2) a hot/cool version that allows people to use yes/no button in addition to making the photos less and more appealing through changes in saturation and size of photos.

Therefore, the final prototypes of the app that were included in the study were these two versions that let people practice regulating their desires and behaviours. Arguably, we can assume both versions of the app could help people distance the visual images of photos through the evaluation and swiping mechanism, but the features in the hot/cool version of the app (i.e., saturation and physically distancing features) are specifically designed to achieve the goal of attenuating temptations and distancing them. This app later was used in

a longitudinal study (see the Procedure section) and people were randomly provided with one version of the app that allows them to use different interaction techniques designed for each version.

Finally, as I intended for people to have an option to provide us with daily feedback, I included a Reflection page so that participants had the option of providing feedback or reflect on their experiences in the app at the time as opposed to waiting till the end of the day to write their feedback (Figure 16).

Method

I conducted a preliminary study to investigate integration of the proposed interactive methods into an application that could be better incorporated into a person's day-to-day experiences. I conducted the study to specifically test the effectiveness of a designed app to help regulate eating behaviour for selected food items from their personalized food library.

The study included two conditions each corresponding to one of two versions of the app, that is, the hot/cool version and yes/no version. The main difference between the two apps is the *hot* and *cool* buttons that allow participants to make a photo of a food item more or less appealing through changes in *saturation* and *distancing*. Figure 16 shows the differences in the designs used for each condition. In both conditions, participants had the same ability to build a personalized gallery and regularly engage in the review exercise to evaluate their choices at the beginning of the day.

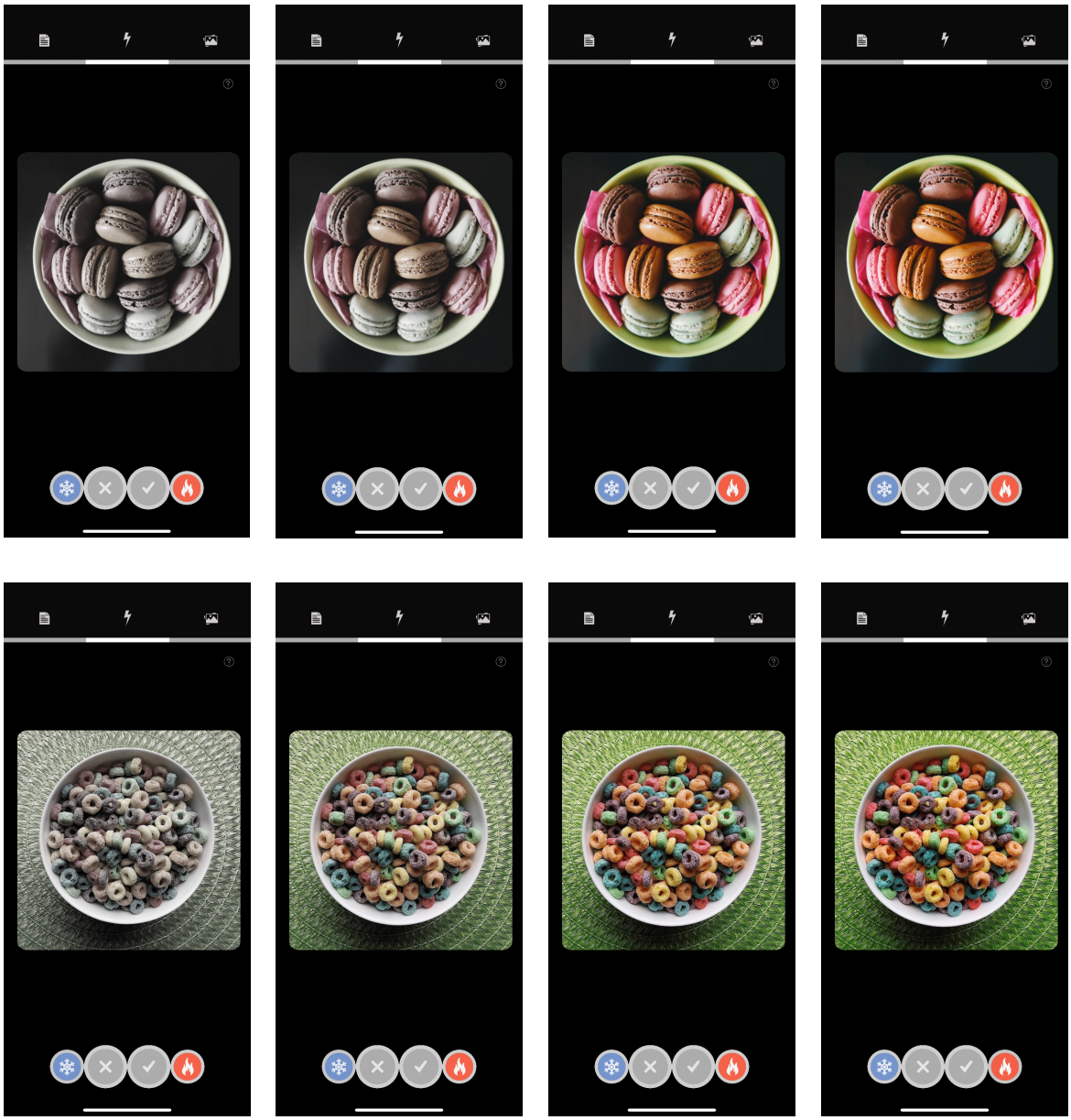


Figure 17. the transition of a photo between cool state (less saturated and distanced) and hot state (more saturated and less distanced). The smooth transition from an almost neutral state (.85) to the least saturation (close to 1, i.e., close to zero but not fully saturated) takes about 4 seconds and transition from the neutral state to the most saturation (close to 1.25, that is the limit after which the photo often would not look natural) takes about 2 seconds. The saturation level of each photo was set before using it in the app to achieve consistency across photos for their neutral state.

Participants

From the 28 participants who agreed to participate, 25 participants completed the study (11 identified as female, 8 identified as male, 1 did not specify, 5 did not report), which was less well-powered than I was hoping due to time limits and the COVID-19 breakout. Three did not continue after the first day and were therefore not included in the analyses. They were asked to participate in the study in exchange for entering a lottery draw to win $50. 10.7% of participants identified as having Asian background, 10.7% as Caucasian, 3.7%, 42.9% as Middle-Eastern, and 7.1% as having other backgrounds. 28.6% of participants also chose not to report.

The effect of COVID-19

I originally intended to recruit around 120 participants for my study, as recommended by Simmons et al. (2013) who suggest aiming for a minimum of 100 participants. However, due to the COVID-19 shutdown and resulting limitations for advertising the study on university campuses or local businesses, I prepared my pre-registration to aim for the minimum sample number calculated in power analysis using G*Power v3.1 software, which was 36 in a period of two months allocated for the study. I took a few routes to advertise the study. I used the Games institute's Twitter account (with more than 1500 followers at the time) and advertised the study through several Facebook channels related to healthy eating (each having more than a few thousand followers). I also combined these methods with more convenience sampling by sharing the advertisement that I had on social media and asking friends and colleagues to share the ad with their friends and family as well. Altogether, the ad was shared in various social media channels such as Facebook, Slack, and Telegram.

An obvious downside of having this number of participants is that many of the pre-registered analyses are going to be underpowered, which could potentially result in higher probabilities of false positive and false negative findings. Therefore, it is important to caution the readers of the results of this study to treat this as a preliminary study for exploring this

approach to conducting such a study. Future research should aim to replicate any notable findings in a larger sample size, which should be more attainable after the COVID-19 outbreak.

Procedure

After a person agreed to participate in the study, they were randomly assigned to one of the two conditions (i.e., based on the order they contacted the experimenter to participate in the study).

They then were instructed to download the application (from App Store and Google Play) and set it up, preferably on the same day that they started to participate, and to start using the app beginning the next day. I primarily communicated with participants through emails, but also answered any questions that I received through other channels of communication (e.g., Facebook messages). Setting up the app took approximately 30 minutes for each participant. This step included entering their participation code in the app, watching a 6-minute tutorial video that explained the purpose of the study and all activities for participants, and visual instruction on how to use the app during the week.

Participants then started building their personalized gallery by going through all photos in the food library once. They were instructed to focus more on food items that they wanted to eat less of, as it was the primary goal of the study to investigate regulation of temptations and unwanted desires of the food items that people want to eat less of. Participants were required to choose at least 10 food items. Although they were not provided with an exact maximum number, they were told not to pick *too many* items for their gallery. Participants then did the first weekly review of all photos that helped them to also set their goals during the week by specifying how much or how frequently they ate or drank a food item and how much/frequently they wanted to have it in the future.

After participants informed the experimenter that they were done with setting up the app, they were asked to answer the first survey, and start using the app and answer nightly surveys beginning the next day. I also sent reminder emails early in the morning and late in the evening to participants during the week of their participation to remind them to do a daily review exercise as soon as they saw the email in the morning, and a nightly survey before the end of the day.

For the daily exercise, I instructed participants to complete one review of all food items at least once a day and as early as possible. They were also asked, especially in the yes/no condition, to reflect on their goals for a moment and think about why they want to eat more or less of the food before swiping a photo left or right. At the end of the intervention period, participants were asked to do a second weekly review of all photos and complete the final survey. Finally, they received an appreciation and debriefing letter, and participants received the $50 monetary reward for participation in the study.

Measures

I used several methods of collecting data and responses in the study including logged data and weekly surveys in the app. I also utilized a first, final and nightly surveys.

In-app weekly surveys—I asked participants to answer questions regarding each food item that they picked at the beginning and at the end of the intervention in the app (i.e., weekly reviews 1 and 2). The surveys were conducted inside the app, once at the beginning of the study after participants chose the food items from the food library and the second time at the end of study after participants finished using the app. Participants viewed the photos of the food items and answered several questions about several important self-regulation variables regarding that photo. Participants were asked about the following questions: momentary temptation towards the food item ("How tempting is this photo at the moment?"), temptation

they experienced in the past week ("How tempted were you to eat more of this food in the past week?"), frequency of unwanted desires towards the food in the past week ("How often did you experience unwanted desires towards the food in the past week?"), and the difficulty of resisting the food in the past week ("How hard was it to resist this food in the past week?") which they rated using a 5-point Likert scale from 1 (not at all) to 5 (a lot). They were then asked about how much/frequently they had the photo in the past week ("How much/frequently did you eat this in the past week") using two questions with a 5-point Likert scales from 1 (less than I'd prefer) to 5 (more than I'd prefer), and then their intention for the next week ("How much/frequently were you planning to eat this in the past week"). The last two questions were specifically used from weekly review 1 for participants to set their goals for the next week, which I also used to distinguish between the foods they wanted to have more or less of in the next week.

Online final survey—I used two online weekly surveys to investigate participants' state before and after the intervention. Online weekly surveys were used to investigate personality differences, their perceived success in self-regulating their eating behaviour and other important aspects of their eating behaviour. As only eight participants answered the first survey, I have focused mainly on the last survey measures and analysis in this thesis, which is discussed more in detail. In the final survey, participants were asked to consider their experience in the past week and then were asked about: their general success in achieving their goals ("In general, how successful have you been in general in achieving the goals?"), with two additional questions regarding their success in reducing food-items in their eating behaviour goals ("1. How successful were you in eating less of the foods that you want to eat less of?"), and their success in increasing food-items in their eating behaviour goals ("2. How successful were you in eating more of the foods that you want to eat more of?"), temptation they experienced in the past week ("How tempted were you toward foods during the past week?"), their experience of unwanted desires in the past week ("How often did you experience

unwanted desires toward foods during the past week?"), and the difficulty of resisting the food in the past week ("How hard was it to resist this food in the past week?") using a 7-point Likert scale from 1 (not at all) to 7 (a lot). They then rate their agreement to statements in a four-item scale using a 7-item Likert scale from 1 (not at all true) a midpoint of 4 (somewhat true) to 7 (very true) to measure their *perceived competency* in regulating their eating behaviour. These items include "I now feel confident in my ability to achieve my eating behaviour goals?", "I now feel capable of achieving my eating behaviour goals.", "I am able to achieve my eating behaviour goals permanently.", and "I am able to meet the challenge of achieving my eating behaviour goals." Inspired by Williams , Deci (1996). They were then asked to answer demographic questions if they had not already completed them in the first survey.

Participants were also encouraged to write their reflections and feedback in the app, nightly surveys, and the final survey open-ended questions.

Pre-registered research questions and hypotheses

The general questions that are being explored in the study are: (1) Is the app effective in helping people of both groups succeed at regulating their desires and eating behaviour in a longitudinal study, and effective on all photos in the gallery? (2) Is the hot/cool app feature design more effective than the yes/no design with only the swiping feature? More specifically, the pre-registered hypotheses regarding all the measures that were collected weekly are:

The intervention will be effective on selected food items after a week of intervention, and using the hot/cool design will be more effective than using the yes/no design (focusing on its effect on regulating food items).

- Considering the foods that people want to eat less of, the intervention will be effective at improving ratings of each food for self-regulation variables: For instance, (1) the

food items will be eaten less after a week of intervention and the photos in the hot/cool condition will show more improvement in terms of perceived amount of food they have eaten during the week (2) the food items will be perceived as less tempting at the moment that they are being reviewed, and create less temptation, less frequent unwanted desires over the last week, and will be less difficult to resist for participants in the hot/cool condition as compared to those in the yes/no condition.

- Considering the food items that people want to eat more of, the intervention will be effective at improving ratings of each food for only related self-regulation variables: (1) participants will eat more of the food items after a week of intervention and participants in the hot/cool condition will show more improvement along these lines. I also explore the changes in level of temptation to explore the effectiveness of using the hot button to increase one's desire for foods a person wants to eat more of.

The intervention will be effective on both groups after a week of intervention and the hot/cool group will be more successful than the yes/no group (focusing on its effect on individuals). This analysis will be done on each participant's top 5 and top 3 choices when considering food items that they want to eat less of, and on their top 3 choices and top 1 choice when considering the food items that they want to eat more of.

- Considering the foods that people want to eat less of, the intervention will be effective at improving ratings of each food for self-regulation variables. For instance, (1) both groups will report improvement in eating foods at the level they intended after a week of intervention. Participants in the hot/cool will be more successful than participants in the yes/no condition, and (2) participants in the hot/cool condition will report experiencing less temptation and less frequent unwanted desires and report less difficulty in resisting tempting foods for the foods they wanted to eat less of, after a week of intervention.

I will also explore if participants in the hot/cool condition report improvement in self-

regulatory variables, including perceived competence, after a week of intervention by comparing responses in first and final surveys.

Deviations from pre-registration—Due to having lower sample size in the study, I had to simplify some of the proposed analyses. The description of the proposed pre-registered analyses and the simplification process is explained in detail. Also, I needed to consider that participants' level of engagement with the app differed. Some of the participants who were provided with the hot/cool app only used the swiping features and hot/cool features for a few days and some used it more regularly. However, when examining logged data to ensure participants had at least used the app and completed the surveys for a few days (i.e., inclusion criteria), the data revealed that two of the participants who were provided with the hot/cool version of the app only used the swiping feature and did not use the hot/cool feature at all. Exploring their data and responses suggested that the issue seemed to be their perception of what they needed to do during the week and what the study required (e.g., thinking about the swiping feature as the main part of daily practice in the study), and not the degree of compliance with the study procedure, as they showed high engagement with the app, completing the surveys and providing feedback and reflections in the app. I therefore paired those participants with the group that did not use the hot/cool version and only used the swiping feature, since this feature is the main point of comparison between the two conditions.

Results

I performed two series of analyses regarding participants' responses in the app and online surveys to investigate the experience of unwanted desires and temptation, and perceived success in achieving their goals. I have also explored the text responses that were provided in the reflection page of the app and nightly surveys and report the general themes of the

responses that were reported regarding the challenges in participants' attempts to pursue their goals.

Weekly in-app reviews (a pre-registered analysis)

I initially used a mixed-effects model using the lmer package in R to test the effect of the intervention (hot/cool) and control (yes/no) conditions on reported measures. However, I had to simplify the model to function later explained in this section.

The mixed-effects model can address the nested structure of data (Raudenbush & Bryk, 2002) as there are observations nested within both food items and people. For those nested within food items, these measures include momentary temptation, temptation in the past week, frequency of unwanted desires, and other variables regarding self-regulation success (e.g., perceived amount eaten of each food and perceived competence). For those nested within people, these measures included perceived amount they had eaten of each food, and perceived competence. Notably, the analysis of weekly app reviews including all photos is the only set of analyses that were not significantly affected by having a lower-than-expected sample size, and thus were sufficiently statistically powered to test the hypotheses. The data allows us to have a conceptual framework to understand the structure of the data as observation within study participants and those within food items, which allows us to adopt a multilevel approach as we have more than fifty food items in the model; that is, we can investigate the effect of the proposed intervention with a focus on people or with a focus on food items.

Dummy variables were used for the *review number* variable that determines the time of review, whether it is the beginning or end of the intervention (1: review #1, 2: review #2), and for *condition* variable that determines which study group a participant belongs to (1: yes/no group, 2: hot/cool group). The variables are measured in review 1 and review 2, therefore the

random slope for the model is the review number that varies within person. For each measure, I first investigated the effect of intervention (i.e., the difference between reported values in time 1 and time 2). Therefore, the fixed effect for that model is *review number*. I then investigated the effect of *condition* of how effective the intervention is, that is, the interaction between the time of review and the study condition. Therefore, the fixed effects for the second model are review number, condition, and interaction term between the two variables. All predictor variables have been centred for the models that are testing the interaction effect.

Reducing Food-Intake Goals

Among 882 total observations, I used these analyses on 246 observations that included data points regarding food-items that participants had the goal of eating less of (i.e., the difference between the amount of each food-item in the past week and the amount of the food-item they intended to have in the future) based on their responses in the first weekly review.

However, the lmer function could not be used, as the number of total random effects were higher than number of observations. This is because of not having enough repeated measures for all photos, that is, many of the photos had been picked only once or twice. Therefore, I simplified the model by calculating the average values of the dependent variables for each food item photo for each analysis.

To examine the effect of intervention for both groups, I collapsed the dependent variable by food-item number, and the review number variables, which calculates the average value for each food-item at review 1 (beginning of the intervention) and review 2 (end of the intervention). I used the lme package in R to compare participants' responses (i.e., 167 observations in total) using a multilevel approach by having review number as the predictor, and food-item number as the fixed-effect within the variable review-number. The model is an equivalent of a one-way repeated measures analysis.

The results show a significant overall decrease in the level of *momentary temptation* towards the food items while looking at them in the app, b = -0.52, SE = 0.17, t_{77} = -3.11, p = .0026 (review 1: M = 3.85, SD = 1.28; review 2: M = 3.36, SD = 1.39). Similarly, the results show a significant decrease in the reported level of *temptation* in the past week towards the food items, b = -0.32, SE = 0.13, t_{78}= -2.56, p = .013 (review 1: M = 3.98, SD = 1.13; review 2: M = 3.69, SD = 1.08). However, they do not indicate a significant decrease in the overall frequency of experiencing *unwanted desires* in the past week towards the food items, b = 0.14, SE = 0.19, t_{77} = 0.73, p = .47 (review 1: M = 3.11, SD = 1.31; review 2: M = 3.25, SD = 1.18). The results also indicate a significant decrease in the *difficulty* of resisting temptations in the past week towards the food items, b = -0.31, SE = 0.14, t_{79} = -2.18, p = .032 (review 1: M = 3.66, SD = 1.20; review 2: M = 3.38, SD = 1.17) and a significant decrease in the *amount of food-intake* they preferred to have when considering the food-items they wanted to eat less of in the past week, b = -0.92, SE = 0.13, t_{78} = -7.14, p = .032 (review 1: M = 3.66, SD = 1.20; review 2: M = 3.38, SD = 1.17).

Also, to compare the effect of intervention between the two groups, I collapsed the dependent variable by food-item number, review number, and condition variables, which calculates the average value for each food-item at the time of review 1 and review 2 for each group. I used the lme package in R to compare participants' responses (i.e., 197 observations in total) using a multilevel approach by having review number as the predictor, and food-items variable as the fixed-effect within the variable review-number. (i.e., the equivalent of a one-way repeated measures analysis) I then investigated the effect of *condition* on how effective the intervention was, that is, the interaction between the time of review and the study condition. Therefore, the fixed effects for the second model are review number, condition, and interaction term between the two variables. To test the interaction effect in the models, the binary variables were not centred. This model, however, is not identical to a repeated measures model. The results of interaction effects are presented in Figure 18.

The results show that the interaction between *review number* and *condition* is a significant predictor of momentary temptations, b = -0.86, SE = 0.32, t = -2.64, p = .0133 (see Figure 18.a; yes/no condition: M_{r1} = 3.65, SD_{r1} = 1.45; M_{r2} =3.64, SD_{r2} =1.34; hot/cool condition: M_{r1} = 4.07, SD_{r1} = 1.18; M_{r2} = 3.17, SD_{r2} = 1.43) that suggests that the hot/cool intervention was more effective at reducing momentary temptation of photos when encountering desirables foods at the moment of reviewing the photos. The results also show that the interaction between *review number* and *condition* is a predictor of temptation experience, b = -0.52, SE = 0.25, t = -2.11, p = .044 (see Figure 18.b; yes/no condition: M_{r1} = 3.82, SD_{r1} = 1.25; M_{r2} = 3.84, SD_{r2} = 1.07; hot/cool condition: M_{r1} = 4.18, SD_{r1} = 0.96; M_{r2} = 3.58, SD_{r2} = 1.10), which suggests that the hot/cool intervention was more effective at reducing temptation of food items. The results also indicate that the interaction between *review number* and *condition* is a predictor of frequency of unwanted desires, b = -1.34, SE = 0.37, t = -3.65, p = .0011, suggesting that participants in the hot/cool condition experienced less momentary temptation (see Figure 18.c; yes/no condition: M_{r1} = 2.61, SD_{r1} = 1.41; M_{r2} = 3.47, SD_{r2} = 1.21; hot/cool condition: M_{r1} = 3.60, SD_{r1} = 1.24; M_{r2} = 3.09, SD_{r2} = 1.26).

The results show that interaction between *review number* and *condition* is a predictor of difficulty, b = -0.80, SE = 0.28, t = -2.90, p = .0072, suggesting that participants in the hot/cool condition experienced less difficulty resisting momentary temptations towards the selected food items (see Figure 18.d; yes/no condition: M_{r1} = 3.17, SD_{r1} = 1.30; M_{r2} = 3.35, SD_{r2} = 1.22; hot/cool condition: M_{r1} = 4.14, SD_{r1} = 0.86; M_{r2} = 3.42, SD_{r2} = 1.21). The results shows that the interaction between *review number* and *condition* is not a significant predictor of the food-intake based on participants' preferences, b = -0.034, SE = 0.26, t = -0.13, p = .90, suggesting that this interaction had a similar effect on both groups (see Figure 18.e; yes/no condition: M_{r1} = 3.35, SD_{r1} = 1.08; M_{r2} = 2.47, SD_{r2} = 1.08; hot/cool condition: M_{r1} = 4.03, SD_{r1} = 0.91; M_{r2} = 3.04, SD_{r2} = 0.96).

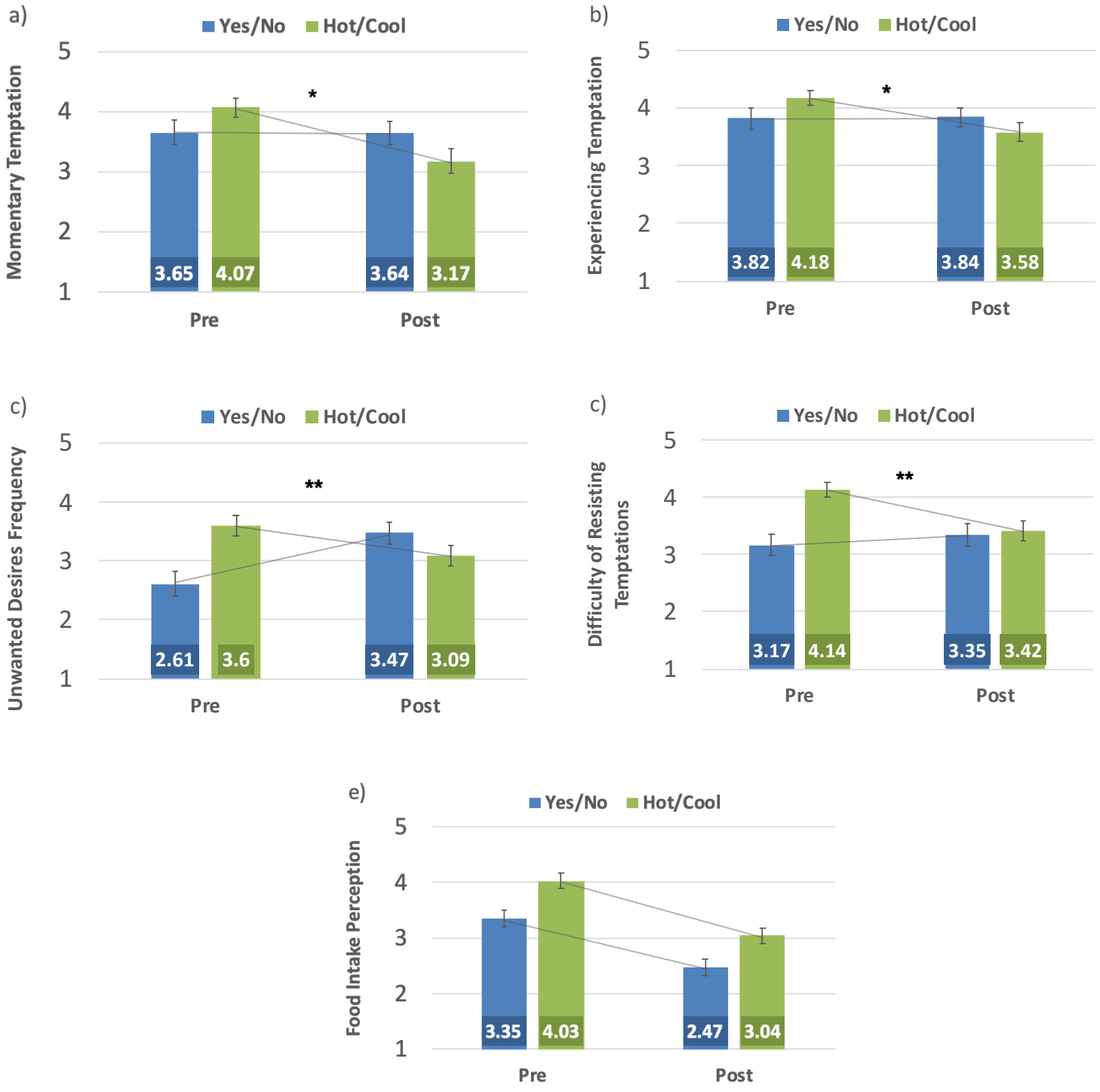


Figure 18. Pre- and post-condition measures of self-regulation success for the foods choices that participants want to eat less of. Error bars represent ±1 standard error of the mean. Significant levels correspond to the interaction effect of condition (yes/no, hot/cool) and review number (pre, post). **p<.01, *p<.05

Increasing Food-Intake Goals

Among 882 total observations, I used these analyses on 301 observations that included data points regarding food items that participants had the goal of eating more of (i.e., the difference between the amount of each food item in the past week and the amount of the food item they intended to have in the future) based on their responses in the first weekly review (see Figure 19.).

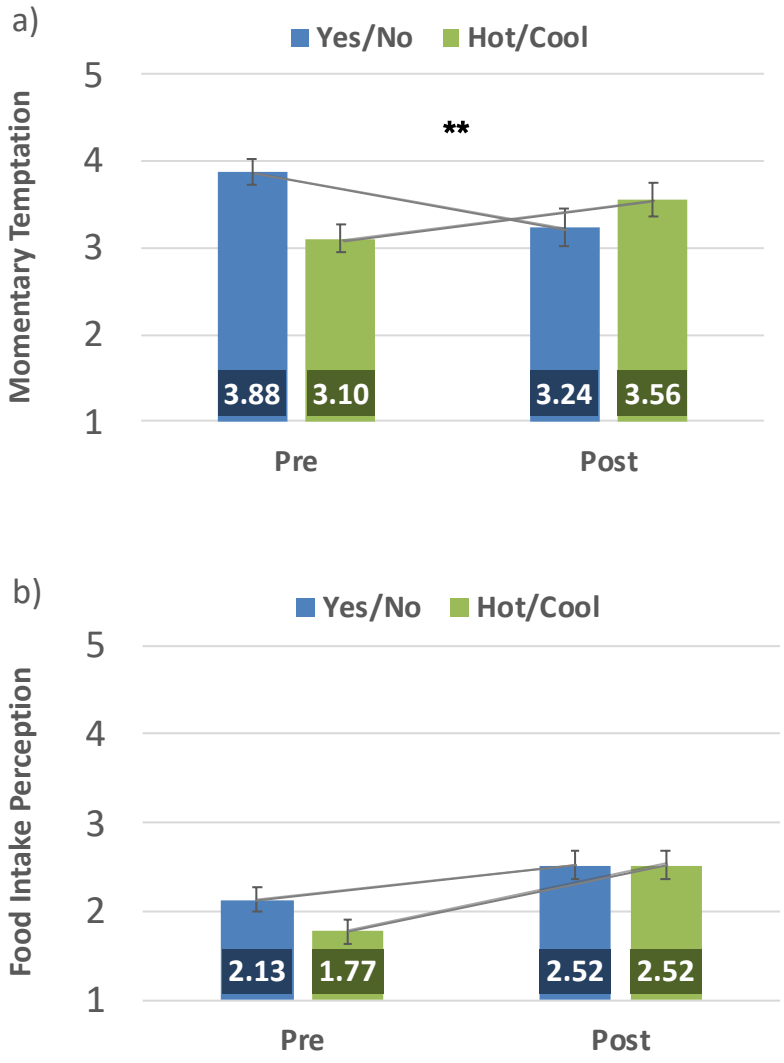


Figure 19. Pre- and post-condition measures of self-regulation success for the foods choices that participants want to eat more of. Error bars represent ±1 standard error of the mean. Significant levels correspond to the interaction effect of condition (yes/no, hot/cool) and review number (pre, post). **p<.01

However, similar to the previous section, the lmer function could not be used because the number of total random effects were higher than number of observations. Therefore, I simplified the model by calculating the average values of the dependent variables for each food-item photo for each analysis.

To examine the effect of intervention for both groups, I collapsed the dependent variable by food-item number, and the review number variables, which calculates the average value for each food-item at review 1 (beginning of the intervention) and review 2 (end of the intervention). I used the lme package in R to compare participants' responses (i.e., 167 observations in total) using a multilevel approach by having review number as the predictor, and food-item number as the fixed-effect within the variable review number. The model is the equivalent to a one-way repeated measures analysis.

The results do not show a significant overall increase in the level of *momentary temptation* towards the food items while looking at them in the app, b = -0.11, SE = 0.17, t_{67} = -0.66, p = .51 (review 1: M = 3.68, SD = 1.48; review 2: M = 3.44, SD = 1.36). Similarly, the results indicate a significant increase in overall the *amount of food intake* based on participants' preference when considering the food items they wanted to eat less of in the past week, b = 0.57, SE = 0.12, t_{78} = 4.62, p < .0001 (review 1: M = 1.97, SD = 0.98; review 2: M = 2.55, SD = 0.98).

Also, to compare the effect of intervention between the two groups, I collapsed the dependent variable by food-item number, review number, and condition variables, which calculates the average value for each food-item at the time of review 1 and review 2 for each group. I used the lme package in R to compare participant's responses (i.e., 167 observations in total) using a multilevel approach by having review number as the predictor, and food-items variable as the fixed-effect within the variable review-number. (i.e., an equivalent of one-way repeated measures analysis for this analysis) I then investigated the effect of *condition* on how effective the intervention is, that is, the interaction between the time of review and the study

condition. Therefore, the fixed effects for the second model are review number, condition, and the interaction term between the two variables. To test the interaction effect in the models, the binary variables were not centred. This model, however, is not identical to a repeated measures model.

The results are shown in Figure 19. They show that the interaction between *review number* and *condition* is a significant predictor of momentary temptations for the foods participants want to eat more of, $b = 1.07$, $SE = 0.33$, $t = 3.29$, $p = .0021$ (Figure 19.a; yes/no condition: $M_{r1} = 3.88$, $SD_{r1} = 1.17$; $M_{r2} = 3.24$, $SD_{r2} = 1.43$; hot/cool condition: $M_{r1} = 3.10$, $SD_{r1} = 1.29$; $M_{r2} = 3.56$, $SD_{r2} = 1.26$), which suggests that the intervention was more effective for increasing the momentary appeal of photos in the hot/cool condition when participants reviewed photos of foods they wanted to eat more of. The results show no interaction effect between *review number* and *condition* as a predictor of food-intake based on participants' preferences, $b = .34$, $SE = 0.24$, $t = 1.44$, $p = .16$, suggesting that the interaction had similar effects on both groups (Figure 19.b; yes/no condition: $M_{r1} = 2.13$, $SD_{r1} = 1.03$; $M_{r2} = 2.52$, $SD_{r2} = 1.07$; hot/cool condition: $M_{r1} = 1.77$, $SD_{r1} = 0.89$; $M_{r2} = 2.52$, $SD_{r2} = 0.98$).

Weekly in-app reviews for top choices (a pre-registered analysis)

Reducing Food-Intake Goals

As described in the pre-registered procedure, I did a similar analysis regarding important self-regulation variables on top 5 and top 3 food-items that participants had the goal of eating less of (i.e., the difference between the amount of each food item in the past week and the amount of the food item they intended to have in the future) based on their responses in the first weekly review. As the result of having a smaller than planned sample size, I should note that the sample size is underpowered, which might result in false positive and false negative results. Therefore, the results should be treated as preliminary findings that require further

investigation. For this reason, I rely less heavily on these findings in the discussion that follows.

To examine the effect of the intervention for both groups, I first created a dataframe that included all dependent variables and I further processed the data to remove rows with missing datapoints before running the multilevel model that removed several observations for each dataframe. The total number of observations were 110 for the top 3 choices and 159 for the top 5 choices. I used the lme package in R to compare participants' responses using a multilevel approach by having review number as the predictor. The random effects in this model included the *participant* variable within the variable *food item* within the variable of *review number* (i.e., the equivalent of a one-way repeated measures analysis).

The results show a significant overall decrease in the level of *momentary temptation* towards the food items while looking at them in the app for both groups for top 5 food items , b = -0.73, SE = 0.17, t_{73} = -4.38, p < .00001 (review 1: M = 3.88, SD = 1.41; review 2: M = 3.30, SD = 1.47) and top 3 food items, b = -0.65, SE = 0.22, t_{50} = -2.94, p = .0049 (review 1: M = 3.88, SD = 1.46; review 2: M = 3.34, SD = 1.52), but did not show an interaction between *review number* and *condition* as a predictor of temptation experience for the top 5 choices, b = -0.15 SE = 0.34, t = -0.47, p = .64, nor the top 3 choices, b = -0.40 SE = 0.45, t = -0.89, p = .37.

Similarly, the results show a significant decrease in the reported level of *temptation* in the past week towards the food items in the app for both groups for top 5 food items, b = -0.58, SE = 0.11, t_{73} = -5.36, p < .00001 (review 1: M = 4.13, SD = 1.06; review 2: M = 3.66, SD = 1.16) and top 3 food items, b = -0.56, SE = 0.13, t_{50} = -4.28, p = .0001 (review 1: M = 4.21, SD = 1.01; review 2: M = 3.72, SD = 1.20), but did not show an interaction between *review number* and *condition* as a predictor of temptation experience in the past week for the top 5 choices, b = -0.20, SE = 0.22, t = -0.94, p = .35, but shows an interaction for the top 3 choices, b = -0.45, SE = 0.25, t = -1.75, p = .087, though did not reach significance, suggesting that participants in the hot/cool

condition experienced slightly lower levels of temptation in the past week for the top 3 choices related to this goal.

The results indicate a slight but not significant decrease in the overall frequency of experiencing *unwanted desires* in the past week towards the food items in the app for both groups for top 5 food items, b = -0.28, SE = 0.17, t_{73} = -1.63, p = .11 (review 1: M = 3.47, SD = 1.32; review 2: M = 3.26, SD = 1.27) and no significant difference for the top 3 food items, b = -0.20, SE = 0.20, t_{50} = -1.04, p = .31 (review 1: M = 3.63, SD = 1.32; review 2: M = 3.49, SD = 1.23), but did not show an interaction between *review number* and *condition* as a predictor of frequency of unwanted desires in the past week for the top 5 choices, b = -0.29, SE = 0.35, t = -0.84, p = .40, and no significant interaction for the top 3 choices, b = -0.08, SE = 0.40, t = -.19, p = .085.

The results also show a significant decrease in the *difficulty* of resisting temptations in the past week towards the food items in the app for both groups for top 5 food items, b = -0.61, SE = 0.13, t_{73} = -4.70, p < .00001 (review 1: M = 3.75, SD = 1.20; review 2: M = 3.28, SD = 1.25) and top 3 food items, b = -0.46, SE = 0.16, t_{50} = -2.90, p = .0055 (review 1: M = 3.75, SD = 1.21 ; review 2: M = 3.42, SD = 1.18), but did not show a significant interaction between *review number* and *condition* as a predictor of difficulty in resisting temptations in the past week for the top 5 choices, b = -0.40, SE = 0.26, t = -1.52, p = .13, and no significant interaction for the top 3 choices, b = -0.50, SE = 0.32, t = -1.60, p = .12, although the pattern of results suggests that participants in the hot/cool condition experienced somewhat less difficulty in resisting temptations in the past week for both top 3 and top 5 choices related to this goal.

The results also show a significant decrease in food-intake based on participants' preferences in the past week for both groups for top 5 food items, b = -0.90, SE = 0.15, t_{73} = -5.81, p < .00001 (review 1: M = 4.13, SD = 1.06; review 2: M = 3.66, SD = 1.16) and top 3 food items, b = -0.90, SE = 0.19, t_{50} = -4.71, p < .00001 (review 1: M = 3.86, SD = 0.99; review 2: M = 3.00, SD = 1.16), but did not show a significant interaction between *review number* and *condition* as a

predictor of food-intake based on their preferences in the past week for the top 5 choices, b = -0.15, SE = 0.31, t = -0.48, p = .63, and no significant interaction for the top 3 choices, b = -0.43, SE = 0.38, t = -1.14, p = .26.

Even though the pattern of results is almost consistent with the previous section that included all food items, the interaction effects are not always significant and do not fully support the hypotheses. This decrease in significant levels could be attributed to the very high standard error rates in interaction analyses compared to the other analyses.

Increasing Food-Intake Goals

Based on the pre-registered procedure, I did a similar analysis as the previous section regarding important self-regulation variables on the top 3 and top 1 food items that participants had the goal of eating more of (i.e., the difference between the amount of each food item in the past week and the amount of the food item they intended to have in the future) based on their responses in the first weekly review.

To examine the effect of the intervention for both groups, I similarly first created a dataframe that included all dependent variables and I further processed the data to remove rows with missing datapoints before running the multilevel model that removed several observations for each dataframe. The total number of observations were 40 for the top 3 choices and 119 for the top 5 choices. I used the lme package in R to compare participants' responses using a multilevel approach by having review number as the predictor. The random effects in this model included the *participant* variable within the variable *food item* within the variable of *review number* (i.e., an equivalent of a one-way repeated measures analysis).

The results show no significant overall increase in the level of *momentary temptation* towards the food items while looking at them in the app (i.e., how appealing the photo looks at the moment) for both groups for top 3 food items, b = -0.16, SE = 0.14, t_{52} = -1.06, p =30 (review 1: M = 3.48, SD = 1.31; review 2: M = 3.27, SD = 1.45) and top 1 food items, b = -0.15, SE = 0.36,

t_{16} = -0.40, p = .69 (review 1: M = 3.41, SD = 1.26; review 2: M = 3.28, SD = 1.64). The results showed an interaction between *review number* and *condition* as a predictor of momentary temptation for the top 3 choices, b = .54 SE = 0.29, t = 1.88, p = .066, though not reached significance, and a significant interaction for the top 1 choice, b = 1.45, SE = 0.67, t = 2.15, p = .048 suggesting that participants in the hot/cool condition found the photos more tempting as the result of the intervention.

The results show no significant overall increase in the food intake based on participants' preferences for the food items while looking at them in the app for both groups for top 3 food items, b = 0.79, SE = 0.12, t_{52} = 6.33, p <.00001 (review 1: M = 1.78, SD = 0.85; review 2: M = 2.57, SD = 1.17) and top 1 food items, b = 1.19 , SE = 0.22, t_{16} = 5.32, p = .0001 (review 1: M = 1.41, SD = 0.59; review 2: M = 2.61, SD = 1.09), but no interaction between *review number* and *condition* as a predictor of food intake for the top 3 choices, b = .063, SE = 0.25, t = 0.25, p = .80, and a significant interaction for the top 1 choice, b = .44, SE = 0.45, t = 0.98, p = .34 suggesting that participants in the hot/cool condition found the photos more tempting as a result of the intervention.

Final Survey

Twenty-five of the twenty-eight participants completed the last survey, out of which only eight participants also completed the first survey. The compliance rate for filling out the first survey was very low, probably because it took a considerable amount of time to set up the app in the initial phase. Since most of the pre-registered analyses regarding the weekly online surveys were dependent on having pre-post test designs to have repeated measures, they would be extremely underpowered (i.e., by having only four sample observations in each cell). I therefore performed a simplified analysis only on the final survey data. Readers should note that these analyses are only exploratory and still quite underpowered; therefore, I reported them but do not rely on them in the discussion of the results.

Final Survey—I performed one-sample t-tests (two-tailed) on variables regarding perceived success and self-regulation reported in the final survey against the scale midpoint. The results of two-tailed one-sample t-tests revealed overall perceived success in pursuing one's goals for the week to be higher than the mean score, t_{23}= 1.94, p = .065 (M = 4.58, SD = 1.47; Cohen's d =.39) although did not reach significance, that is only slightly higher than average, and success in reducing food intake goals, t_{24}= 2.43, p =.023 (M = 4.76, SD = 1.56; Cohen's d =.49), and success in increasing food intake goals, t_{24}= 2.88, p = .0082 (M = 4.68, SD = 1.18; Cohen's d =.39). The results also show greater perceived competence although did not reach significant, t_{24}= 1.87, p = .073 (M = 4.54, SD = 1.43; Cohen's d =.38); however, it is important to consider that periodic (i.e., pre-post) measures of perceived competence are more important for the context of this study than the absolute values of perceived competence.

Conducting the one-sample t-test to test the opposite hypothesis shows a slightly higher than average level of temptation, t_{24}= 3.12, p = .0046 (M = 4.84, SD = 1.34; Cohen's d =.63), but not in the frequency of experiencing unwanted desires, t_{24}= 0.68, p = .51 (M = 4.24, SD = 1.76; Cohen's d =.14), or difficulty of resisting temptations, t_{24}= 1.17, p = .25 (M = 4.40, SD = 1.71; Cohen's d =.23).

I also performed independent sample t-tests on measures of success and self-regulation reported in the final survey. The results showed no significant difference between the groups regarding overall success in pursuing goals set for the week, t_{23}= -.33, p = .74 (*swiping condition*: M = 6.63, SD = 2.04, *hot/cool condition*: M = 4.43, SD = 1.25; Cohen's d = 1.32), success in food intake reduction goals t_{24}= -.17, p = .87 (*swiping condition*: M = 6.63, SD = 2.04, *hot/cool condition*: M = 4.43, SD = 1.25; Cohen's d = 1.32), success in food intake increase goals t_{24}= .50, p = .61 (*swiping condition*: M = 6.63, SD = 2.04, *hot/cool condition*: M = 4.43, SD = 1.25; Cohen's d = 1.32)., level of temptation, t_{24}= -.84, p = .41 (*swiping condition*: M = 6.63, SD = 2.04, *hot/cool condition*: M = 4.43, SD = 1.25; Cohen's d = 1.32), and frequency of unwanted desire, t_{24}= -0.082, p = .94,

(*swiping condition*: *M* = 6.63, *SD* = 2.04, *hot/cool condition*: *M* = 4.43, *SD* = 1.25; Cohen's *d* = 1.32), Slightly less difficulty in resisting temptation, t_{23}= -0.87, *p* = .40 (*swiping condition*: *M* = 6.63, *SD* = 2.04, *hot/cool condition*: *M* = 4.43, *SD* = 1.25; Cohen's *d* = 1.32). slightly greater perceived competence, but not significant, t_{23}= -0.86, *p* = .40 (*swiping condition*: *M* = 6.63, *SD* = 2.04, *hot/cool condition*: *M* = 4.43, *SD* = 1.25; Cohen's *d* = 1.32).

Discussion

Considering the data analyses with more statistical power, the findings of this study suggest that this intervention could be effective to some extent in regulating desires and the experience of temptations, and it can also help people with the difficulty of resisting tempting food items. The intervention seemed to be effective in terms of the short-term change in the amount food intake in both versions of the app; however, there was no significant interaction between condition. Therefore, we can tentatively conclude that the hot/cool version of the app seems effective in changing temptation towards food items and the frequency of unwanted desires towards them; however, we cannot conclude that the hot/cool version is more effective than the yes/no version in changing the food intake for all the food items. Furthermore, readers should note that even finding a short-term difference in food-intake would not necessarily suggest a long-term effect. Therefore, I should highlight that changing the level of temptation and frequency of unwanted desires is particularly notable among the findings of the study.

The findings of the repeated measures analysis also suggest that the interaction between the condition and the review number variables seems to be the major predictor of the changes in self-regulatory variables such as momentary temptation, temptation level, frequency of unwanted desires, and difficulty of resisting temptations. It also suggests an opposite effect in some situations, for example, increase in frequency of unwanted desires for the yes/no

version of the app. Therefore, this designed practice was particularly effective when participants had the option of cooling down the tempting photos that they wanted to regulate. The results of the quantitative analysis show that the intervention is more effective when using the hot/cool feature of the app.

These analyses and observations of participants' reflections both led to the conclusion that the interactive experience that was created in the app for practicing self-regulation actually provided a desirable setting for the study (from the standpoint of the experimenter); that is, it created experiences of temptation and desire towards the photos, and therefore it made it difficult for those who did not use the hot/cool feature to effectively battle the temptations and reduce the unwanted desires towards the food items. The differences found in participants' report regarding temptation while reviewing the photos reenforces this conclusion that using the app to practicing interaction techniques versus lack of that practice had a lasting effect on participants.

Experience of temptation and engagement with the app

Participants provided both positive and negative feedback about their experience and some specifically about advantages or limitations of the app, as they evidently engaged differently with the app. Some found the app very well-designed, and some found, for example, having a limited number of foods boring and wanted to be able to engage longer with the application. Therefore, I discuss their responses regarding a few important aspects of their experiences with the app and possible influential factors on some aspects of their engagement with the app and the study.

Frequency of using the app—As previously highlighted several times, one important aspect of this intervention is for the design to be an actual practice of resisting temptation by creating a situation that actually *requires* practicing self-regulation. Therefore, an important question

in this type of intervention is whether creating tempting situations could backfire and make it more difficult for people to regulate their affective states and behaviours. In the study, participants were advised to use the app every day or as many days as they can (and at least three days in the week) with the expectation that they might not be able to fully comply with this instruction. For instance, one participant who used the hot/cool feature frequently mentioned *"This app totally backfires if I don't take the time to dull or brighten the images. Or honestly probably even when I do. It just seems to remind me those foods exist and my brain is like hey yeah I totally wanted that when I saw it before, let's eat it."* Or, for example, a participant who did not use the hot/cool features of the app mentioned "*This app is just encouraging me to eat them more.*" Or "*Seeing the photo of my favorite foods is very tempting for me …*". Therefore, an important observation that requires further investigation is whether there is an appropriate frequency of using the app for both conditions, and if this effect would also negatively impact the people who use the hot/cool version of such an application.

Engagement with the app

I have also made other observations that highlight the importance of the intervention design and the ability of researchers to engage participants with self-regulation apps. It is also important to engage participants with the app in the appropriate time, for example, at the beginning of the day or when they struggle with unwanted desires or conflicting motivations. For example, one participant mentioned "*I found it very helpful to complete this before lunch because then I can make my fallback bad foods look unappetizing and make the healthy foods look appetizing. If somebody had brought donuts to the office, I think I would just do this before walking around too much more at the office to hopefully change how good they look in my mind since I usually eat pretty healthy breakfast solo.*" We have anticipated this issue and instructed participants to use the app as early as they can, and also send them daily reminders. However, it is important for researchers to investigate how they can engage participants effectively with the app at the

right or *best* time during the day.

Participants also mentioned some suggestions that they were thinking would help them engage better with the app. For example, even though I tested the speed of transition between visually hot and cool states of a photo before using it, some participants expressed their desires of being able to go through the review practice faster. We do not know if granting this wish would help or hurt their progress; however, it is worth exploring to create a more flexible hot/cool feature that participants can modify based on their preferences. A few participants also requested a better feedback mechanism in the app to remind them about their goals and ratings, and a few others also made suggestions that they thought would motivate them, which are likely to be from their experiences using other Health-related mobile applications. Although some of these preferences might be biased by what some other apps advertise to be effective or commonly used in their designs, for example, calorie counting preferences, they need further attention to improve the interactive experience of the app.

Conclusion

While some of the ideas used in this chapter are simple interaction techniques, we can apply them in a wide range of novel technologies that facilitate the implementation of such a technique in our daily life. For example, as mobile applications continue to become more widely accessible, or as virtual and augmented reality technologies are becoming more accessible to the public and accordingly more pervasive, applying these design approaches to improve self-regulation by mediating people's experience of desire can become both easier and more effective.

In addition, it is noteworthy that even though some aspects of these simple technological interventions are not used by researchers, they are long known in marketing industries who are actively trying to create the opposite effect, that is, tempting people to purchase and

consume products through various creative methods. For example, companies use these methods to change the way food images are displayed in advertising and in online stores to make their items tempting. This fact suggests that there may be economic and political challenges that might prevent us from applying our methods to solve health-related issues. Therefore, researchers need to also invest in designing technologies that could directly help people resist temptation, especially when such temptations are being imposed on them from outside forces, such as the advertising industry.

The contributions of this chapter included designing a mobile application (Foodie Willpower) that incorporates the findings of Study 4 in addition to design elements that were inspired by our self-regulation knowledge that allows researchers to test these interaction techniques in a design prototype that could be used longitudinally in an intervention similar to a commercial product. It also included providing empirical evidence regarding testing the mobile application in a longitudinal study to impact people's experience of unwanted desires and temptations. Participants' success in achieving their eating-behaviour goals (Study 5) provides preliminary evidence demonstrating the effectiveness of design features and interaction techniques for regulating desire and behaviour, including some evidence regarding the features that were specifically designed to help people reduce the temptation of food items and distance them when using the app.

Chapter 10
Conclusion & Future Work

In this chapter, I first provide a brief overview of the contributions of this thesis by elaborating on the direction of the thesis in general, and then provide more details regarding future work stemming from the contributions of each chapter.

This thesis included five studies, one commentary and one critical review (see Figure 20). Most of the studies are focused on understanding how interactive designs and design elements can impact self-control or self-regulation processes.

Figure 20. Overview of the studies, review, and commentary that is included in the thesis.

The findings of Study 1 can help researchers better understand the role of design models of free-to-play games and challenges players experience when playing these games. These findings inspired me to more closely investigate how we can compensate for the limitations of current design models or help researchers and designers create interventions for self-control and self-regulation improvement that ideally could also be applied in this context. I focused on designing and evaluating self-control games in Study 2 to create a game that

could impact and improve players' capacity for self-control with the purpose of assisting people with lower levels of self-control who might be prone to self-regulation failure in various contexts, such as the context of Study 1, that is, resisting and overcoming self-regulation conflicts when playing free-to-play games.

Study 2 coincided with a series of controversies surrounding ego-depletion (i.e., the resource model of self-control) and working memory improvement, which were the theoretical basis for the studies that were intended to build upon the findings of Study 1 and Study 2. Study 2 takes a small step towards creating a slightly nuanced design of a self-control game and examining players' experience in this game that could be used for a longitudinal study. In this thesis, I argue that these complex, challenging and nuanced versions of self-control games could be used to address some aspects of the controversies in addition to making self-control games that might transfer their benefits to a range of related behaviours as well. In the commentary regarding the ego-depletion model, I also discussed the benefits of using such games and some of the main issues that need to be addressed to pave the way for future research.

While these controversies create exciting opportunities for studying self-control improvement theories and designing for self-control improvement, they create difficulties for contributing to applied research on improving self-control capacity. Studies 3-5, therefore consisted of a change of direction, while keeping the same overarching objectives of the thesis. These studies investigate interaction techniques that could more directly mediate people's experience, and therefore improve self-regulation of behaviour related to the context of that behaviour more effectively. Furthermore, in starting with a more general approach and then focusing on a specific context of eating behaviour, my review of the concept of psychological distance and Studies 3-5 demonstrated the possibility of using psychological insights to investigate interaction techniques and to design interactive technologies that influence people's self-regulation in the context of eating behaviour, which could also be explored in

various other domains.

By focusing on these approaches, we can modify how people visually perceive and more effectively intervene to help address specific challenges, such as experiencing unwanted desires and strong temptations. Therefore, the contributions of these studies can be revisited in many different contexts in which interactive technologies could help modify peoples' experience and help them resist temptations. It can also be taken into consideration for investigating new designs that could be used in an intervention or ultimately be integrated with technologies that people frequently use in everyday life.

In addition to the findings and insights that were generated through the research that is presented in this thesis, there is a need for more research including both empirical studies and in-depth theoretical research to increase our understanding of self-regulation and self-regulation improvement, especially, to create and learn more about it with respect to implementing and testing interactive designs. The insights generated from research could help people mitigate the negative effects of some interactive technologies on self-regulation or increase the positive aspects of interactive technologies on self-regulation and self-regulation improvement.

Limitations & Future Work

Study 1 showed that we could draw valuable knowledge regarding players' experience in Freemiums games and about people's experience using a Freemium design model in general. Future research should investigate the effect of using this phenomenon on various game designs and the corresponding monetization strategies that are used to engage customers and persuade them to purchase in-app goods. A more in-depth analysis of various Freemium games could, for example, shed more light into motivational mechanisms that play an important role in these situations. Researchers should also

consider investigating the possible effect of these mechanisms on more vulnerable populations, such as those who are prone to depression or addiction, that might be significantly impacted as the result of engaging with such designs. Even though the findings of Study 1 provided interesting observations and insights regarding players' behaviour and experience, further qualitative research and experimental studies could shed light into the nature of the relationship between Freemium designs, purchasing decisions, and self-regulation. An experimental study of behavioural economics aspects of player behaviour can help researchers establish a causal relationship. Notably, this requires having a platform to test these hypotheses, for instance, by creating a successful free-to-play game or collaborating with a company that has adopted this approach.

Study 2 highlights the promising aspect of using videogames to measure and improve self-control processes. The findings of the study about my proof-of-concept design shows that games with simple mechanics and low fidelity could be used to practice self-control, for example, games with similar mechanics (e.g., Subway Run, Super Mario Run, Temple Run) can incorporate these self-control mechanics. Other researchers could explore self-control mechanics in more complex, higher-fidelity games, or explore other existing commercial games that may already incorporate some self-control mechanics (e.g., Virtual Cop, Ghost Blitz). Future work needs to focus on exploring the design process of self-control games to properly challenge self-control processes, instead of using self-control tasks as a self-control practice.

In chapters 6-9, I focused on improving self-regulation strategies to help people psychologically distance themselves from unwanted desires and regulate their behaviour. In the brief critical review about psychological distance, I also pointed out the wide range of phenomena related to the connection between psychological distance and self-

regulation and self-regulation improvement mechanisms, which opens a new perspective for designing simple novel interactive technologies that could help people regulate their desires and behaviours. This research could benefit from a systematic review of the current state of research about design for self-control and self-regulation improvement in order to identify gaps and limitations of current designs across all domains of self-regulation.

Study 3 explored the impact of only one psychological distance dimension. However, there is room for exploring how technology can impact various dimensions of psychological distance through modifying the visual features of what people see when encountering a tempting object or situation. In addition, the findings of the study suggest that future work should thoroughly investigate theoretical connections between abstraction and psychological distance, which is proposed by CLT, through critical analysis of its literature and rigorous replication of theoretical claims made by the theory.

In Studies 4 and 5, I explored mitigating the tempting aspects of a food using a simple interaction technique that could be easily implemented using mobile or tablet devices. Even though one could consider the modification I have used in the studies as augmented reality, I encourage other researchers to use more advanced augmented reality techniques for the same purpose. For instance, using devices such as the Microsoft HoloLens could expand the capability to make changes to what people are directly seeing through the headset, and may therefore greatly strengthen the effect of such interventions.

Lastly, my final study requires replication to confirm its preliminary findings, as discussed in Chapter 9. Future work that uses an interactive design for longitudinal studies of self-regulation improvement should also focus on investigating designing and testing

various elements of a design that could increase engagement with the features of the app that are crucial for an effective self-regulation practice. This is particularly important to consider and explore in future work especially if researchers adopt my proposed approach of creating designs that simulate temptations and desires that people experience in self-regulation conflict situations.

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