

---


Electronic Theses and Dissertations, 2004-2019

---

2019

## Designing Calorie Counter Smartphone Applications for Effective Weight Loss

Sharlin Milliard  
*University of Central Florida*

 Part of the [Applied Behavior Analysis Commons](#)  
Find similar works at: <https://stars.library.ucf.edu/etd>  
University of Central Florida Libraries <http://library.ucf.edu>

This Masters Thesis (Open Access) is brought to you for free and open access by STARS. It has been accepted for inclusion in Electronic Theses and Dissertations, 2004-2019 by an authorized administrator of STARS. For more information, please contact [STARS@ucf.edu](mailto:STARS@ucf.edu).

---

### STARS Citation

Milliard, Sharlin, "Designing Calorie Counter Smartphone Applications for Effective Weight Loss" (2019).  
*Electronic Theses and Dissertations, 2004-2019*. 6753.  
<https://stars.library.ucf.edu/etd/6753>

DESIGNING CALORIE COUNTER SMARTPHONE APPLICATIONS  
FOR EFFECTIVE WEIGHT LOSS

by

SHARLIN TAMARA JANINE MILLIARD  
B.S. Utrecht University, 2006  
M.S. Utrecht University, 2009

A thesis submitted in partial fulfillment of the requirements  
for the degree of Master of Science in Modeling and Simulation  
in the School of Modeling, Simulation, and Training  
in the College of Sciences  
at the University of Central Florida  
Orlando, Florida

Fall Term  
2019

Major Professor: Barbara Truman

© 2019 Sharlin Tamara Janine Milliard

## **ABSTRACT**

Poor dietary choices and lack of physical activity are two main contributing factors for the increasing prevalence of overweight and obesity in the United States. Overweight and obese individuals are at risk for developing major life-threatening diseases. Weight loss is an effective means for reversing these adverse health effects, and smartphone applications (apps) may be an effective means for supporting weight loss outside of formal clinical settings. This study involved identifying factors that contribute to effective weight loss to compare with functionality commonly found in a sample of calorie counter apps. A content analysis was performed using a design framework that included a conceptual model describing the interaction of behaviors for effective weight loss and functional design requirements based upon behavior change and motivation to achieve weight loss. The requirements were used to analyze the presence of features in a sample of popular calorie counting apps, to infer their capability in supporting users' motivation to achieve weight loss. Results indicated that app features might not provide sufficient support to facilitate effective weight loss. Lack of supportive features affects perceived autonomy, relatedness, and competence, reducing motivation. This study provided guidelines to improve the design of calorie counter apps to include more features that support users as they engage in weight loss behaviors. The guidelines may become practical for use in Mobile Health (mHealth) apps used as part of formal and informal weight management strategies. Implications for future research involving wearable technologies and the use of gamified design strategies are discussed.

## ACKNOWLEDGMENTS

I am very grateful to have a lot of support throughout this study. Most importantly, I would like to thank God for wisdom, strength, and guidance throughout this entire process. I would also like to thank my committee, current and former. First, I would like to thank Dr. Barbara Truman, my current committee chair, for sharing her profound knowledge which allowed for the improvement of this study, her diligence in giving me detailed feedback and coordinating my virtual defense, and her encouragement which helped me reach the finish line. Secondly, I would like to thank Dr. Joseph Fanfarelli, my first chair, for helping with the conceptualization of this study, his shared vision in ensuring the production of work that I can be proud of, his detailed feedback, his continued encouragement, and immense patience. Thirdly, I would like to thank Dr. Patricia Bockelman, my second chair, for her guidance in helping me make progress on my study in a very short amount of time, for the insight in shaping the core elements of this study, her encouragement, and her persistent belief in my success. I would also like to thank Dr. Richard Hartshorne for sticking with me throughout this process and his thoughtful insights. Furthermore, I would like to thank Dr. Francisca Yonekura for her support throughout all the years I have known her, for stepping in last minute as committee member, and insightful comments for improving this study. I'd also like to thank my family and close friends for their unwavering support and prayers. And last but not least, I would like to thank my friend Sushinova Kupke, for her support, for her willingness to be the person I bounced ideas off, and for relying on her engineering background to help shape my model and functional requirements.

To the individuals mentioned here and those that I may have forgotten to mention, thank you all for your help and support, I will be forever grateful.

## TABLE OF CONTENTS

LIST OF FIGURES .....	viii
LIST OF TABLES.....	ix
CHAPTER ONE: INTRODUCTION .....	1
Purpose of Study.....	3
CHAPTER TWO: LITERATURE REVIEW .....	4
Prevalence of Adult Overweight and Obesity in the U.S. ....	4
Consequences of the Prevalence of Overweight and Obesity .....	6
Treating Overweight and Obesity .....	7
Dietary and Physical Activity Objectives.....	8
Counseling.....	9
Behavioral Strategies.....	11
The Effectiveness of Behavioral Interventions for Weight Loss .....	13
Promoting Weight Loss with Calorie Counters .....	14
The Effectiveness of Calorie Counters for Weight Loss.....	17
Intervention Components Improve Effectiveness of Calorie Counters .....	18
Feature Gap of Calorie Counters.....	20
Self-Determination Theory .....	24
Internalization.....	24

Basic Psychological Needs .....	26
Literature Review Summary .....	27
CHAPTER THREE: METHODOLOGY .....	29
Analysis of Calorie Counter Applications .....	30
Part 1: Design Framework Development .....	31
Conceptualizing Weight Loss .....	31
Defining Design Requirements .....	34
Part 2: Procedure for Analysis of Calorie Counter Applications.....	39
Inclusion and Exclusion Criteria.....	40
Selection Strategy .....	41
Screening .....	41
Analysis .....	41
Methodology Summary.....	42
CHAPTER FOUR: FINDINGS.....	43
Sampling Findings .....	43
Analysis Findings .....	45
Goal-setting.....	46
Self-Monitoring .....	50
Support .....	53

Discussion.....59

Limitations.....61

Research Implications .....63

CHAPTER FIVE: FUTURE RESEARCH .....64

APPENDIX: CALO-RE TAXONOMY BEHAVIOR CHANGE TECHNIQUES .....66

LIST OF REFERENCES .....71



## LIST OF FIGURES

Figure 1. Taxonomy of Human Motivation. Adapted from (Ryan & Deci, 2000a; Silva et al., 2008). .....	25
Figure 2. Theoretical Foundations and Content Analysis Methodology.....	30
Figure 3. Weight Loss Behavior Model.....	32
Figure 4. Summary of the Selection Process of Calorie Counter Apps for Analysis.....	44

## LIST OF TABLES

Table 1. BTI Effectiveness Factors Compared to Calorie Counter App Features .....	21
Table 2. Factors Associated with Effective Behavioral Interventions for Weight Loss .....	31
Table 3. Calorie Counter Application Functional Requirements.....	35
Table 4. Inclusion Criteria .....	40
Table 5. Calorie Counter Apps Selected for Analysis.....	45
Table 6. Analysis Findings for Goal-setting 1 .....	47
Table 7. Analysis Findings for Goal-setting 2 .....	48
Table 8. Analysis Findings for Self-Monitoring 1 .....	50
Table 9. Analysis Findings for Self-Monitoring 2.....	51
Table 10. Analysis Findings for Support 1 .....	54
Table 11. Analysis Findings for Support 2.....	56

## CHAPTER ONE: INTRODUCTION

The U.S. population consumes more foods high in added sugars, fats, and oils as opposed to vegetables, fruits, and lean meats (Bentley, 2017). Although there are several contributing factors for unhealthy dietary choices, one major contributor is the availability of a plethora of easy, low-cost, and highly processed foods (Wright & Aronne, 2012). Furthermore, the number of adults that engage in physical activity in accordance with the federal physical activity guidelines is also not ideal (Clarke, Norris, & Schiller, 2017). Poor dietary choices and lack of physical activity are two main contributing factors of the increasing prevalence of overweight and obesity in the United States. Overweight and obese individuals are at risk for developing major diseases such as type II diabetes, cancer, cardiovascular disease, and hypertension (Williams, Mesidor, Winters, Dubbert, & Wyatt, 2015).

Weight loss is an effective means of reversing the adverse health effects of overweight and obesity. Smartphone applications (apps) may be an effective means for supporting individuals' weight loss on their own outside of formal clinical settings. The use of smartphone apps has become ubiquitous due to the immense growth of smartphone ownership. According to the Pew Research Center (2017), 77% of Americans now own a smartphone in comparison to only 35% in 2011. More than half (58%) of smartphone owners have installed at least one health related mobile app to self-monitor their physical activity, diet, weight loss, or to learn new physical activity exercises (Krebs & Duncan, 2015). Health and fitness mobile apps account for the majority of health-related apps in the Apple app store (Apple Inc., n.d.) with physical activity training and calorie counting self-monitoring apps being among the most common (Sama, Eapen, Weinfurt, Shah, & Schulman, 2014; West et al., 2012). The popularity of physical activity training and calorie counting self-monitoring

apps is not surprising because of an ongoing quest for fitness and achievement or maintenance of a healthy diet, but also the prevalence of overweight and obese individuals. Many individuals turn to calorie counter apps for these purposes as these apps are often free or low cost, and easily accessible. Calorie counter apps are capable of providing some weight loss support as they model a user's current health state and simulate a more ideal health state through feedback.

Calorie counters available in the Apple app store (Apple Inc., n.d.) and on Google Play (Google, n.d.) claim to be effective tools to support weight loss and weight maintenance. Claims may be justifiable as the apps' main feature supports the self-monitoring of diet, physical activity, and weight. Consistent self-monitoring of *behaviors* that affect weight loss and weight maintenance, have been found to stimulate dietary and physical activity behavior change (Turner-McGrievy et al., 2013) both in the short- and long-term (Samdal, Eide, Barth, Williams, & Meland, 2017), and, consequently, calorie counting has been found to be associated with positive effects on weight loss (Baker & Kirschenbaum, 1993; Burke, Wang, & Sevick, 2011; Dombrowski, et al., 2012; Hartmann-Boyce, Johns, Jebb, & Aveyard, 2014; Wang et al., 2012). However, research has not found compelling evidence to support that claim. Instead, research suggests that calorie counters do not facilitate significant weight loss indicating their ineffectiveness as self-directed weight loss tools (Allen, Stephens, Dennison Himmelfarb, Stewart, & Hauck, 2013; Wharton, Johnston, Cunningham, & Sterner, 2014). Additionally, a contributing factor is that the frequency of using calorie counters for self-monitoring gradually decreases (Burke et al., 2011; Laing, 2014; Turner-McGrievy et al., 2013) indicating the apps' inability to motivate users to achieve their weight loss goals. The ineffectiveness of calorie counters to support significant weight loss and their inability to motivate users raises the following questions. What features should calorie counter apps have to facilitate motivation and effective weight loss? Are these features missing in commercial calorie counter apps?

## Purpose of Study

The purpose of this research study was to identify factors associated with successful weight loss and analyze features present in commercially available calorie counter apps to infer their capability in supporting users' motivation to achieve effective weight loss. This research contributed to the literature on the effectiveness of commercial calorie counters apps. Jake-Schoffman et al. (2017) noted, "... identification of high quality commercial apps is essential for research, clinical practice, and to inform the development of the next generation of commercial apps" (p. 2).

This study explored the literature to identify factors that contributed to effective weight loss and motivation, to compose recommended functional design requirements. Chapter two provides the literature review that established theoretical foundations that informed the creation of a weight loss model and definition of functional requirements. Chapter three presents how the formulated design requirements compared to the functional features of popular calorie counter apps. The current state of apps was identified in chapter four, indicating functional features that may be lacking to support motivation and effective weight loss.

## **CHAPTER TWO: LITERATURE REVIEW**

Chapter two explores clinical obesity treatments and practices to discover key factors that contribute to effective weight loss. Gaps in the functionality of calorie counter apps in promoting weight loss are described based on the effectiveness factors and descriptions of how individuals can be motivated to achieve weight loss in the context of the Self-Determination Theory (Deci & Ryan, 1985) are presented.

### **Prevalence of Adult Overweight and Obesity in the U.S.**

Dietary habits of the U.S. population have worsened over a 44 year (Bentley, 2017, p. 5; Wright & Aronne, 2012). Between 1970 and 2014, the availability of food in the U.S. has increased and more food has been consumed by the U.S. population (Bentley, 2017). The U.S. population has chosen to consume more grains, foods high in added fats and oils, and high in added sugars and sweeteners as opposed to more nutrient-dense foods (vegetables, fruits, lean meats, low-fat dairy) despite their increased availability (Bentley, 2017). This diet is in direct contrast to the evidenced-based 2015-2020 Dietary Guidelines for Americans (U.S. Department of Health and Human Services, 2015) which specify limiting the intake of calories from added sugars and added fats to promote overall health and prevent chronic disease.

In addition to the deterioration of the U.S. population's dietary habits, the number of adults that engage in aerobic and muscle strengthening physical activity has been on the low end for almost two decades (Clarke et al., 2017). In 2016, only 21.7% of adults 18 and over met the 2008 federal physical activity guidelines of participating in at least 150 minutes of moderate aerobic exercise per week, 75 minutes per week of vigorous aerobic exercise, or an equivalent combination of both

moderate and vigorous aerobic exercise, and muscle strengthening activities twice weekly (Clarke et al., 2017, p. 46).

The U.S. population's dietary and physical inactivity habits has, in part, contributed to the prevalence of overweight or obese American adults (U.S. Department of Health and Human Services, 2015; Wright & Aronne, 2012) being that obesity is commonly caused by consuming an excess amount of highly caloric and fatty foods without engaging in adequate physical activity to expend the excess calories (Centers for Disease Control and Prevention, 2016; Wright & Aronne, 2012). An individual is considered to be overweight or obese if weight is above what is considered to be a healthy weight based on height (Centers for Disease Control and Prevention, 2016).

Commonly, Body Mass Index (BMI) which is expressed as weight in kilograms divided by height in meters squared ( $\text{kg}/\text{m}^2$ ) is used to classify individuals into weight categories (Fryar, Carroll, & Ogden, 2016). A person is considered to be overweight with a BMI between 25 and 30, obese with a BMI over 30, and extremely obese with a BMI 40 or higher (Centers for Disease Control and Prevention, 2016; Fryar et al., 2016). More than two in three (70.6%) adults 20 and older were overweight or obese between 2013 and 2014 (Fryar et al., 2016). More than one in three (32.7%) adults were found to be overweight, more than one in three (37.9%) were obese, and about one in thirteen adults (7.7%) were considered to be extremely obese (Fryar et al., 2016, p.1). Of the adults 20 and older, 38.7% of men and 26.5% of women were overweight, 35% of men and 40.4% of women were obese, and 5.5% of men and 9.9 % of women were extremely obese (Fryar et al., 2016, p.4).

## Consequences of the Prevalence of Overweight and Obesity

The prevalence of overweight and obesity is not without consequence (Wyatt, Winters, & Dubbert, 2006). Research revealed that overweight and obesity has adverse health, psychosocial, and economic effects on the 70.6% of the U.S. population that are overweight or obese (Guh et al., 2009; Mokdad et al., 2003; Must, 1999; Williams et al., 2015; Wyatt et al., 2006). Firstly, concerning health, overweight and obesity are a major risk factor for developing disease. Overweight and obesity have been found to be associated with the incidence of the following co-morbidities: type II diabetes, all cancers (except esophageal, pancreatic, and prostate), all cardiovascular diseases, asthma, liver and gallbladder disease, osteoarthritis, chronic back pain, hypertension, stroke, dyslipidemia, sleep apnea, and gynecological issues (Guh et al., 2009; Mokdad et al., 2003; Must, 1999; Williams et al., 2015; Wyatt et al., 2006). Acknowledging the immense amount of diseases associated with overweight and obesity is of no surprise that life longevity is also negatively affected. According to Jensen et al. (2014), the higher an individual's BMI the greater the risk of mortality. Secondly, psychosocial effects associated with overweight and obesity due to social weight stigma are depression, anxiety, bulimia, body dissatisfaction, low body-esteem, and low self-esteem (Williams et al., 2015; Wyatt et al., 2006). Finally, the co-morbidities associated with overweight and obesity are among the most expensive concerning health-care costs and use of health-care services (Kent et al., 2017; Wyatt et al., 2006). According to Kent et al. (2017), when compared to healthy weight individuals, the annual healthcare costs for overweight individuals is 12% higher and for obese individuals 36% higher. Kent et al. (2017, p. 18) found that the increase in healthcare costs were the highest for medication (18% for overweight and 68% for obese individuals), second highest for inpatient care (12% for overweight and 34% for obese individuals), and third highest ambulatory care (4% for overweight and 26% for obese individuals).



## Treating Overweight and Obesity

Looking at the prevalence of overweight and obesity and the associated adverse effects on health, psychosocial well-being, and the health costs to overweight and obese individuals, it is urgent and necessary to reverse these adverse effects. Research has indicated that weight loss is an effective means to reduce the risk factors associated with overweight and obesity (Anderson & Konz, 2001; Blackburn, 1995; Brown, Buscemi, Milsom, Malcolm, & O'Neil, 2016; Diabetes Prevention Program Research Group, 2002; Goldstein, 1992; Kritchevsky et al., 2015; Wing et al., 2011).

Clinical treatment of overweight and obesity is dependent on an individual's specific condition and it can consist of healthy lifestyle changes, behavioral weight loss treatment programs, medication, or bariatric surgery (National Heart, Lung, and Blood Institute (NHLBI), n.d.). For this study, the sole focus was on behavioral, or life-style modification, interventions for weight loss.

A weight loss of at least 5% of baseline weight has been regarded as a validated criterion for effective treatments that produce clinically significant health benefits (Blackburn, 1995; Williamson, Bray, & Ryan, 2015). However, a 5%-10% weight loss provides even greater health benefits (Brown et al., 2016; Wing et al., 2011) and will assist in the sustainment of those benefits (Williamson et al., 2015). The American Heart Association Task Force on Practice Guidelines (AHA), American College of Cardiology (ACC), and The Obesity Society (TOS) have stipulated guidelines for diagnosing and treating overweight and obesity in which they recommend U.S. clinicians to prescribe an initial weight loss goal of 5%-10% (Jensen et al., 2014). AHA, ACC and TOS recommend clinicians to prescribe an evidence-based behavioral approach that aims to change an obese or overweight individual's lifestyle to bring about weight loss (Jensen et al., 2014). Behavioral treatment interventions (BTIs) are considered the go-to standard for treating overweight and obesity (Jensen et al., 2014).

The AHA, ACC and TOS have advised clinicians treating overweight and obesity to prescribe a comprehensive lifestyle program in which patients are assisted with reducing their nutritional intake and increasing their physical activity, through the use of behavioral strategies that have been found to be effective for behavior change (e.g., setting weight loss goals, monitoring dietary intake for improved dietary choices, cognitive therapy) and consequently weight loss (Jensen et al., 2014). Changing the behavior or lifestyle of overweight and obese individuals is critical to successful weight loss (Olson, Bond, & Wing, 2017). Behavioral interventions for weight loss should be designed to accomplish this change of lifestyle. Formal interventions should consist of trained health professionals (e.g., psychologists, primary care physicians, nutritionists, dieticians, or trained interventionists) 1) prescribing dietary and physical activity objectives to produce weight loss, 2) delivering intensive (i.e., number of sessions over a period of time) counseling sessions, in which a patient's performance is reviewed, the patient is given feedback as a means for problem-solving, and is instructed on several weight loss topics, and 3) employing behavioral strategies or behavior change techniques (BCTs) to increase adherence to objectives (Olson et al., 2017; Wadden, Webb, Moran, & Bailer, 2012). The following sections will discuss the main components of behavioral interventions.

#### *Dietary and Physical Activity Objectives*

A major factor for success in achieving weight loss is to alter one's dietary behaviors. One should aim to reduce calories and consume nutritionally dense foods (Bentley, 2017; U.S. Department of Health and Human Services, 2015). A change in dietary habits in combination with an increase in physical activity is advised (Jensen et al., 2014). However it should be noted that, changing dietary habits while restricting calorie intake has been suggested as having a similar weight

loss outcome, in the short-term, as if in combination with an increase in physical activity (Franz et al., 2007; Hartmann-Boyce et al., 2014). Patients should be prompted to combine calorie restriction and physical activity, in the short-term, to preserve muscle mass, and in the long-term for weight maintenance (Wadden et al., 2012).

Patients are usually advised to reduce their dietary intake by 500 to 1,000 calories per day to produce a weight loss of one to two pounds per week (Butryn, Webb, & Wadden, 2011). AHA, ACC and TOS advise women to be prescribed 1,200 to 1,500 calories per day, and men 1,500 to 1,800 (Jensen et al., 2014). Having such dietary goals help patients reduce their dietary intake to create a calorie deficit that will lead to weight loss (Butryn et al., 2011). Dietary regimens prescribed to help reduce daily calories are, for example, low-fat, low-carbohydrate, Mediterranean, and low glycemic load diets (Wadden et al., 2012). Although there are a variety of diets that claim to be better than the other, the type of diet one chooses to follow or the macronutrient composition of meals does little to affect weight loss (Wadden et al., 2012). Calorie restriction and adherence to this goal are the determinants of weight loss success (Franz et al., 2007; Guth, 2018; Wadden et al., 2012).

### *Counseling*

Reducing calories requires counseling patients to first become aware of (i.e., assess) their caloric intake, to then modify their eating habits by counting calories (Guth, 2018). Modifying caloric intake requires patients to understand the need for reduction in addition to understanding the composition of foods (Guth, 2018). Patients' understanding of their individual need for caloric reduction and the nutrient composition of foods is necessary to make appropriate food choices for weight loss (Guth, 2018). Rosenbaum et al. (2018), suggested that higher nutrition literacy significantly predicts weight loss at six months ( $b=-0.63$ ,  $p=0.04$ ). This finding indicates that patients

should be educated on not only what the healthy food options are, but also on the nutrient composition of foods, how certain foods will affect their bodies, and consequently their weight. According to Foster, Makris, and Bailer (2005), patients in behavioral interventions are adult learners who need to be involved in their behavior change. They need to know *what* the specific short-term goals are, *how* to identify facilitators and barriers to success, and *why* they need to change their behavior (Foster et al., 2005).

Behavioral interventions consist of individual or group counseling sessions in which patients are provided with motivational and behavioral strategies throughout the process of achieving their weight loss goals. In clinical settings, patients should participate in the behavioral intervention for six months or more and receive on-site high intensity (fourteen sessions or more within six months) group or individual counseling (Jensen et al., 2014). LeBlanc et al. (2011) suggest greater weight loss is achieved in interventions that are more intense. Patients lost 4-7 kg (6% of baseline weight) during their first year with twelve to twenty-six sessions, compared to 1.5-4 kg (2.8% of baseline weight) in interventions with fewer than twelve sessions (LeBlanc, O'Connor, Whitlock, Patnode, & Kapka, 2011, p. 436). Similarly, Wadden et al. (2014) concluded that more weight is lost if accompanied by more treatment sessions. Based on the studies they reviewed, eight sessions produced a weight loss of 3.5 kg compared to 6.6 kg lost with fifteen sessions (Wadden, Butryn, Hong, & Tsai, 2014). These findings indicated that intense and continued personalized weight loss counseling may be essential for helping overweight and obese individuals lose clinically significant weight (Tsai, Remmert, Butryn, & Wadden, 2018).

### *Behavioral Strategies*

Evidence-based behavioral strategies, or BCTs, are used to facilitate behavior change in patients' dietary and physical activity behaviors to promote weight loss. A BCT has been defined as "... an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behavior; that is a technique is proposed to be an 'active ingredient' (Michie et al., 2013, p. 82). Michie et al. (2011) identified a total of forty BCTs for changing physical activity and eating behaviors which were classified into the Coventry, Aberdeen & London Refined (CALO-RE) taxonomy. CALO-RE has been used in research studies to not only identify the specific "active ingredients" used in behavioral interventions but also to uncover which BCTs are associated with positive behavior change.

Behavioral strategies serve as a vehicle for learning and adopting skills to change unfavorable behaviors (Anderson, Shapiro, & Lundgren, 2001; Foster et al., 2005). A variety of strategies can be used, that have been found to be effective for behavior change, such as goal-setting, self-monitoring, feedback on performance, problem solving, motivational interviewing, and graded tasks (Hankonen et al., 2014; Lara et al., 2014; Samdal et al., 2017). For this study, the focus was more on goal-setting and self-monitoring that are key for facilitating behavior change (Foster et al., 2005). Patients are counseled to set goals and record their dietary and physical activity behaviors as a means to monitor progress towards achieving those goals.

Behavioral interventions are characterized by employing strategies to facilitate setting specific and measurable goals; *goal-setting* (Wadden & Foster, 2000). Specific, measurable goals allow for the assessment of goal achievement in addition to the identification of problem areas and strategies to overcome them. Patients are prescribed clear, measurable daily dietary and physical activity goals for an initial (i.e., by month six) weight loss of 5%-10% (Olson et al., 2017). Patients learn and practice

skills on how to achieve those goals through the identification of factors that hinder or facilitate progress. It is vital that counseling focuses more on identifying barriers to and solutions for success instead of only providing advice on how to solve problems. Research by Franz et al. (2007), suggest that interventions solely focusing on giving advice has little effect on weight loss. Focusing more on barrier identification and solutions enables patients to develop skills to effectively manage problems (Foster et al., 2005). Behavioral interventions are designed to help patients identify specific cues that trigger negative behaviors and provide reward, or enable patients to reward themselves, for the adoption of positive behaviors (reinforcement) (Anderson & Konz, 2001; Foster et al., 2005). Behavioral interventions encourage focus on small changes instead of larger ones. Focusing on smaller changes helps to maintain motivation in the short-term and to achieve larger changes in the long-term.

*Self-monitoring* is regarded as the cornerstone of behavioral interventions (Butryn et al., 2011). Patients are asked to keep a detailed record of their food intake (e.g., what was eaten, caloric content, fat content), physical activity (e.g., duration and intensity), and weight on a daily basis (Butryn et al., 2011). The food record is vital in the beginning to uncover eating patterns to determine which dietary habits should be altered to achieve weight loss (Butryn et al., 2011). Daily weighing is beneficial to recognize the relationship between food eaten, physical activity, and body weight (Olson et al., 2017). This strategy provides behavioral data, to patient and counselor, for evaluation. The data is reviewed to assess if behaviors are positively, negatively, or have no impact on progress towards achieving pre-set goals (Anderson et al., 2001; Butryn et al., 2011). Self-monitoring enables behavior change because of the frequent review of records in relation with goals, produces accountability and reinforcement (Webb & Wadden, 2017). Self-monitoring has been found to stimulate dietary and physical activity behavior change (Turner-McGrievy et al., 2013) both

in the short- and long-term (Samdal et al., 2017), and, consequently, calorie counting has been found to be associated with positive effects on weight loss (Dombrowski et al., 2012; Hartmann-Boyce et al., 2014). Traditionally, self-monitoring has been done using notebooks. However, advances in technology provide new ways for monitoring behaviors with tools such as pedometers, smartphone applications, wearable activity trackers, and wireless scales (Webb & Wadden, 2017).

### The Effectiveness of Behavioral Interventions for Weight Loss

Behavioral interventions are complex and no two are the same (Dombrowski et al., 2012). Variation in intervention features produces very different interventions. Interventions can vary in treatment intensity, the type and amount of behavioral strategies used, the use of different types of diets to control food intake, and the use of dissimilar tools or technologies for self-monitoring. These variations make it a bit difficult to pin-point what particular mix of features will produce weight loss. However, there seems to be a consensus among researchers that behavioral interventions do provide more weight loss, in comparison to usual care, minimally intensive treatments, or no treatment at all (Fitzgibbon et al., 2012; Hartmann-Boyce et al., 2014; Hassan et al., 2016; Johns, Hartmann-Boyce, Jebb, & Aveyard, 2014; LeBlanc et al., 2011; Wadden et al., 2014; Webb & Wadden, 2017). Researchers have also indicated that behavioral interventions rarely produce clinically significant weight loss (5-10% of baseline weight) but if they do, it may depend on their features (Hartmann-Boyce et al., 2014; Johns et al., 2014; Wadden et al., 2014). Features that were found to be associated with effective interventions include:

- Comprehensive interventions consisting of behavioral strategies, and diet and physical activity objectives (Hartmann-Boyce, 2014; Hassan et al., 2016; Nan et al., 2017).

- Intensive counseling, coaching, or dietician involvement to educate patients on nutrition topics. The more contact, the more reinforcement and increase in motivation (Appel et al., 2011; Booth, Prevost, Wright, & Gulliford, 2014; Hartmann-Boyce et al., 2014; LeBlanc et al., 2011).
- Interventions with a longer duration (e.g., one year) (LeBlanc et al., 2011; Nan et al., 2017).
- Behavioral strategies associated with weight loss to facilitate adherence to objectives include goal-setting, self-monitoring, provision of instruction and information, goal review, demonstrations (Dombrowski et al., 2012; Hankonen et al., 2014; Hartmann-Boyce et al., 2014; Lara et al., 2014; Samdal et al., 2017).

#### Promoting Weight Loss with Calorie Counters

Behavioral interventions for weight loss are usually delivered in primary care with a personal physician (LeBlanc et al., 2011). However, the interventions are time-consuming and expensive for the patient as well as the healthcare provider (Butryn et al., 2011; Olson et al., 2017) making the interventions unfavorable for delivery outside of clinical trial settings (Thomas & Bond, 2018). This finding indicates that behavioral interventions are unavailable to many of the 70.6% of the U.S. population that are obese or overweight. Nevertheless, advances in digital technology provide a means for time and cost savings, as well as a wider reach for behavioral interventions. Not only can interventions be delivered remotely, which increases adherence rates, (Thomas & Bond, 2018), but healthcare providers can also use digital technology as part of treatment to encourage self-care and provide feedback, in addition to digital technology being able to empower the 70.6% of overweight and obese individuals in the U.S. to take charge of their own health (Levine, Savarimuthu, Squires,



Nicholson, & Jay, 2015; Raaijmakers, Pouwels, Berghuis, & Nienhuijs, 2015; Thomas & Bond, 2018; Tufano & Karras, 2005).

In particular, the proliferation of mobile technologies and their application in supporting the achievement of health objectives has given rise to a novel health delivery method, mHealth (mobile health) (World Health Organization (WHO), 2011). The National Institute of Health (NIH) Consensus Group defines mHealth as "... the use of mobile and wireless devices to improve health outcomes, healthcare services and health research" (HIMMS, 2012). mHealth professes healthcare delivery anytime, anywhere, across time, space, and location, and encompasses technologies that are wireless, mobile, or wearable (e.g., smart scales, smartphones, smart or fitness watches) (Gee, Greenwood, Paterniti, Ward, & Miller, 2015). mHealth technologies provide a viable option for the delivery of behavioral interventions for weight loss (Raaijmakers et al., 2015). mHealth also includes smartphone applications (apps) designed to support users in the attainment of weight loss goals. These applications provide a promising means for supporting overweight and obese individuals to track or self-monitor their daily food intake and physical activity for weight loss and weight management (Wadden et al., 2012).

There are hundreds of thousands of applications available on all major smartphone application stores for tracking weight and physical activity behaviors. More than half (58.23%) of smartphone owners have installed at least one mHealth application to self-monitor their physical activity, diet, or weight loss (Krebs & Duncan, 2015). So-called calorie counters such as MyFitnessPal or Lose It! allow users to keep a digital food diary to monitor their daily dietary intake. Food items are entered manually via database lookup, barcode scanning of food packaging, or even by taking a photo. The amount of calories per food item and other nutrient information (e.g., macronutrient composition and vitamin percentages) is also visible to the user. Daily food entries

are categorized by meals and total calories consumed are automatically tallied so that users can view their total calories consumed per meal and per day. Calorie counters also feature a digital exercise diary for monitoring daily physical activity behavior. Exercise can be entered manually, automatically shared via fitness tracker, or automatically tracked via smartphone sensors. Users can view their total energy burned and other related data (e.g., reps, sets, and steps). Furthermore, users can also set and track dietary goals (e.g., daily maximum calorie consumption), physical activity goals (e.g., the minimum amount of workouts per week), and weight loss goals (e.g., lose one lbs. per week). Calorie counters automatically calculate the total amount of calories left to be consumed per day, based on food and exercise diary data, for a user to meet their goals. Most calorie counters also include diet and fitness informational blog posts, a social media component, and the functionality to push prompts or reminders to the user.

With regard to the components of behavioral interventions (counseling, behavioral strategies, and dietary and physical activity objectives), smartphone technology and, in particular, calorie counters have the functionality capable of delivering these interventions (Payne, Lister, West, & Bernhardt, 2015). Some behavioral interventionists have utilized calorie counters as part of their treatment package offering the applications predominantly for self-monitoring, goal-setting, and immediate feedback, while others have utilized calorie counters to deliver remote interventions providing counseling by phone call (Ross & Wing, 2016), email (Wharton et al., 2014), text-messages (Carter, Burley, Nykjaer, & Cade, 2013), podcast (Turner-McGrievy et al., 2013), and even video messages (Thompson-Felty & Johnston, 2017). These apps have the potential to eliminate the need for intensive in-person counseling sessions saving time and costs; enable anywhere, anytime access to weight related health resources; provide the means for continuous performance review and just-in-time feedback, facilitating easy self-monitoring of weight-related behaviors and goals (Raaijmakers

et al., 2015; Thomas & Bond, 2018); and deliver a means for interactivity, personalization, and engagement (Direito et al., 2014). Additionally, there is also a future potential of calorie counters to provide simulated support.

### The Effectiveness of Calorie Counters for Weight Loss

Commercially available calorie counter applications are widely available and marketed as tools for achieving weight loss success with slogans such as “Lose weight with MyFitnessPal” (Under Armour Inc., 2009) or “Lose weight once and for all” (FitNow Inc., 2008). As was previously discussed, research has suggested the potential of calorie counter applications for weight loss success, their potential to save costs, and the potential to facilitate the scalability of behavioral weight loss interventions.

Recently, several researchers have conducted feasibility and pilot studies investigating the efficacy of weight loss intervention delivery via calorie counter applications. Some studies have evaluated efficacy utilizing commercially available calorie counters while others have custom developed calorie counter applications modeled after their commercially available counterparts. Findings suggested that calorie counter smartphone applications may be useful tools for weight loss regardless of the application being commercially available or custom developed (Flores Mateo et al., 2015; Semper, Povey, & Clark-Carter, 2016). However, it must be stated that there are only a small number of studies investigating the effectiveness of calorie counters for weight loss, these studies have small sample sizes, and they were mainly conducted short-term (Flores Mateo et. al, 2015). The following sections discuss study findings comparing the use of calorie counters in combination with intervention components (e.g., counseling, educational weight loss topics, and dietary interventions) to the sole use of a calorie counter application to support weight loss.

### *Intervention Components Improve Effectiveness of Calorie Counters*

Several studies indicated that calorie counters produce weight loss but very minimally (Allen et al., 2013; Carter et al., 2013; Laing et al., 2014; Stephens, Yager, & Allen, 2017; Thompson-Felty & Johnston, 2017; Wharton et al., 2014). Particularly, Wharton et al. (2014) assessed the feasibility of using calorie counters for self-monitoring and weight loss. They compared self-monitoring using the Lose It! application to two other methods: using the smartphone's memo feature and using paper and pencil. In contrast to the calorie counter group, these two control groups also received a one-on-one counseling session, weekly emails to encourage healthy eating and a personalized diet plan. Results indicate that participants using the Lose It! application trended towards less weight loss than participants in the control groups (Wharton et al., 2014). The control groups' diet also trended towards improvement while Lose It! did not assist study participants in improving their diet. These results suggested that the use of calorie counters alone may not be sufficient to produce clinically significant weight loss or improve dietary intake. The missing element may very well be the dietary counseling that the control groups received. Notably, Flores Mateo et al. (2015) suggested that behavioral interventions that combined calorie counter applications with intervention components are associated with more weight loss than other types of interventions; this includes the use of calorie counters on their own. A study by Ross & Wing (2016) evaluated the effect of modern self-monitoring technology (i.e., calorie counter, Fitbit tracker, and Aria smart scale) on weight loss in comparison to standard methods (i.e., calorie reference book, pedometer, scale, paper self-monitoring booklets). Participants ( $n = 80$ ) were given an introductory weight loss class and randomized to one of three groups: standard self-monitoring, self-monitoring with modern technology, and self-monitoring with modern technology in combination with phone calls. The researchers found that participants lost over 5% ( $p = 0.035$ ) of their baseline weight, over three

months, using modern self-monitoring technology alone, or in combination with 14 phone calls from interventionists giving tips on standard behavioral weight loss techniques (e.g., goal-setting, relapse prevention, problem-solving, and seeking social support). Participants who received phone calls lost more weight than participants using just modern self-monitoring technology. This result is not surprising as counseling sessions have been indicated as a key component for producing weight loss in behavioral interventions (Appel et al., 2011; Booth et al., 2014; Hartmann-Boyce et al., 2014; LeBlanc et al., 2011; Tsai et al., 2018). Allen et al. (2013) also indicated that counseling might be key for weight loss via calorie counter. The researchers investigated the efficacy of calorie counters by comparing in-person counseling sessions in combination with self-monitoring using MyFitnessPal to the sole use of the application. Two participant groups were instructed to use MyFitnessPal to track dietary intake and physical activity. These two groups also received in-person physical activity and nutritional counseling (recommendations for reducing calories and increasing nutrient-dense foods while decreasing energy-dense foods). One of these two groups received intense counseling (weekly for the first month then biweekly for month two through month six) and the other less intense counseling (twice during month one then monthly from month two through month six). The third group was instructed to use MyFitnessPal and received one basic nutrition counseling session. Allen et al. (2013) found a trend for more weight loss when MyFitnessPal was used in addition to intensive or less intensive counseling as opposed to utilizing the application alone to achieve weight loss. Similarly, a study by Stephens et al. (2017) indicated the potential of commercially available calorie counters to support weight loss when used in combination with counseling. Results found by Stephens et al. (2017) suggested that Lose It! is capable of producing weight loss in combination with coaching and dietary education. Participants were randomized into two groups: Lose It! + health coach and a control group. Both groups received a counseling session on limiting the intake

of alcohol and sugary beverages during the baseline visit. The Lose It! + health coach group received an additional 30-40 min counseling session on the nutrient density of foods, energy balance, and physical activity in addition to them identifying goals to work on with the health coach. The participants also received frequent (three times daily up to once per week) tailored text messages from a health coach. The control group was instructed not to use any applications. Stephens et al.'s (2017) intervention was successful in that participants lost a significant amount of weight. Seven of the 31 (24%) participants changed weight categories; five lost enough to move to the normal weight category, and two lost enough to move from obese into the overweight category. Similarly, another study found that most (85%) participants lost 5% of their initial weight at 12 weeks utilizing a custom developed application in addition to weekly weigh ins, weight loss lessons (e.g., benefits of self-monitoring), weekly text messages from interventionist based on application data, brief video lessons (e.g., identifying and removing high-fat food items from kitchen cupboards), daily reminders, and personalized goals (Thomas & Wing, 2013).

#### *Feature Gap of Calorie Counters*

Findings suggested that the use of calorie counters alone produces minimal weight loss (Allen et al., 2013; Wharton et al., 2014; Laing et al., 2014; Stephens et al., 2017). With so many calorie counter applications commercially available, this brings claims of their potential to support weight loss for health improvement into question, as well as their ability to deliver behavior interventions remotely. Calorie counters have many features in common with behavioral treatment interventions. The features associated with effective treatment interventions were compared to the typical features of these apps in order to begin to understand why they produce minimal weight loss. This comparison is summarized in Table 1.

Table 1. BTI Effectiveness Factors Compared to Calorie Counter App Features

<b>BTI Effectiveness Factors</b>	<b>Featured in Apps?</b>	<b>App Feature Description</b>
<b>Dietary objectives</b>	✓	Apps allow users to set their total daily calories, total calories per meal, and total macro nutrients.
<b>Physical activity objectives</b>	✓	Users can set weekly number of workouts and workout duration.
<b>Weight objectives</b>	✓	Users can set a target weight and a weekly weight loss goal to achieve that goal.
<b>Self-monitoring</b>	✓	The apps feature a food diary to track diet, physical activity diary to track physical activity, and weight tracker to track weight.
<b>Goal-setting</b>	✓	Apps allows users to set dietary, physical activity, and weight goals.
<b>Counseling (intense)</b>	-	Apps do not provide sufficient personalized feedback or counseling.
<b>Long treatment duration</b>	-	Users do not maintain use of apps over a long period which hampers goal achievement.

The most common features among calorie counter applications are self-monitoring and (Azar et al., 2013; Bardus, van Beurden, Smith, & Abraham, 2016; Lister et al., 2014; Payne et al., 2015). Individuals can use the apps to input their dietary, physical activity, and weight behaviors which are visually presented. The apps help users to stay in line with the goals they set by providing some immediate feedback based on the user’s input. For example, calories consumed and energy expended is automatically compared to a daily calorie goal set by the user. The amount of calories left to be consumed for the day, based on consumption and expenditure, will be immediately visible to the user. In contrast to behavioral interventions, apps typically do not prescribe individually tailored dietary and physical activity objectives to the extent necessary for effectiveness. They provide a recommended amount of daily calories based on the recommended weight loss of 1 lb. per week relative to the user’s desired goal achievement date. Concerning physical activity, it is left to the user to decide the level of daily physical activity that they will engage in to meet their goals.

Although calorie counters feature immediate feedback, with regard to total calories consumed, macro nutrient composition of meals (including which food items contribute the most to a particular macro nutrient), nutrient composition of food items, and providing general diet

information via the blog feature, this may not be enough to support substantial weight loss. The apps are missing personalized counseling on appropriate objectives based on previous behavior or goals, coaching for problem identification and overcoming barriers and nutrition education to support goal progress (Direito et al., 2014; Chen, Cade, & Allman-Farinelli, 2015; Rivera et al., 2016; West et al., 2012). Additionally, calorie counters do not provide counseling assistance to appropriately set effective goals (Davis et al., 2016). Studies suggest that calorie counters are capable of impacting weight loss, but the inclusion of features for personalized counseling, which includes dietary education and performance feedback, may lead to more weight loss (Carter et al., 2013). Jacobs, Radnitz, & Hildebrandt (2017) found substantial weight loss in a study utilizing Noom, a commercially available calorie counter application which features a variety of methods for counseling delivery. About half of the participants lost 5% of their baseline weight while using Noom. This result may be due to individualized feedback, gamification, and experiential learning in the form of challenges that focus on specific behaviors, personalized education built into tasks, and adaptivity based on goals and task completion that are featured in Noom.

The modest effectiveness of calorie counters could also be explained by minimal adherence to their use for self-monitoring that may be hampering clinically significant weight loss (Stephens et al., 2017; Thompson-Felty & Johnston, 2017; Turner-McGrievy et al., 2013). Notably, Thompson-Felty & Johnston (2017) suggested a trend in increased app adherence when apps include dietician feedback concerning to the quality of food consumption. This trend seems to suggest that adherence to self-monitoring in addition to personalized counseling may be determinants for calorie counter effectiveness and weight loss success (Allen et al., 2013; Thompson-Felty & Johnston, 2017). Research suggests that overweight and obese individuals tend to self-monitor more often using calorie counters as opposed to other methods such as paper diary, smartphone memo feature, or



website (Allen et al., 2013; Carter et al., 2013; Laing, 2014; Wharton et al., 2014). Additionally, studies have suggested a relationship between adherence to self-monitoring, using calorie counters, decreased calorie consumption (Turner-McGrievy et al., 2013) and increased weight loss (Stephens et al., 2017; Thomas & Wing, 2013). Turner-McGrievy et al. (2013) have also suggested that adherence to self-monitoring using calorie counters predicts weight loss; the more one logs, the more weight is lost (Jacobs et al., 2017; Stephens et al., 2017). Nevertheless, the frequency of using calorie counters gradually decreases (Carter et al., 2013; Laing, 2014; Turner-McGrievy et al., 2013) impeding their effectiveness for weight loss.

The gradual decrease in the use of calorie counters suggests that calorie counters do not sufficiently support the maintenance of motivation for app use and to lose weight. Content analysis studies have indicated insufficient incorporation of evidence-based BCTs in calorie counter applications (Azar et al., 2013; Chen et al., 2015; Direito et al., 2014; West et al., 2012). The inherent purpose of BCTs is to redirect causal factors that regulate behaviors (Michie et al., 2013). In other words, BCTs promote motivation for behavior change (Gillison, Rouse, Standage, Sebire, & Ryan, 2019). Calorie counters' inability to keep users engaged indicates a lack of, insufficient, or ineffective incorporation of features to facilitate motivation (Laing, 2014; Turner-McGrievy et al., 2013) and consequently produce significant weight loss. When it comes to changing health behaviors, the behavior needs to be maintained for change to occur. To be motivated means to be moved, energized, or activated to engage in a certain behavior (Ryan & Deci, 2000a). Deci & Ryan's (1985) Self-Determination theory will help in understanding how motivation is initiated and maintained.

## Self-Determination Theory

The Self-Determination Theory (SDT) is a motivation theory that has often been used to understand the conditions under which an individual will be motivated to engage in health behaviors. The theory posits that there are two types of motivation, intrinsic and extrinsic, that differ based on their locus of causality (i.e., source of motivation). For intrinsic motivation, the source is internal and external for extrinsic motivation. According to SDT, motivation for a behavior that stems from external sources (e.g., pressure, reward, or obligation) is characterized as being controlled and the motivation for a behavior that stems from internal sources (e.g., interest, enjoyment, or value) is characterized as being autonomous (Deci & Ryan, 2015). More controlled motivation is, for example, when a primary care physician tells a patient to lose weight or when someone joins a weight loss competition for some monetary prize. An individual that is autonomously motivated will attach personal value or importance to behavior and engage out of choice and volition.

### *Internalization*

SDT proposes that the motivation to engage in a certain behavior lies on a continuum from amotivation, increasing in degree of autonomy, to intrinsic motivation (See Figure 1). A person's motivation can move from one end of the continuum to the other through internalization. Internalization is the transformation of controlled behaviors to more autonomous behaviors (Deci & Ryan, 2015). For example, a person can initially engage in weight loss activities because of a cash prize for the "biggest loser." Over time, however, the person will endorse the benefits of weight loss and internalize it as being meaningful or worthy to their health.



of their values (e.g. live longer, be healthy, be seen, be loved, be respected etc.) to make the behavior of losing weight more autonomous. For effective and long-term maintenance of weight loss, research has suggested that autonomous motivation is key (Teixeira, Silva, Mata, Palmeira, & Markland, 2012). Autonomous motivation has been found to predict adherence to self-monitoring (Webber, Tate, Ward, & Bowling, 2010), predict weight loss (Williams, Grow, Freedman, Ryan, & Deci, 1996), predict long-term maintenance of physical activity (Silva et al., 2011), and autonomously motivated physical activity was found to predict healthy eating (Mata et al., 2009). Interestingly, controlled motivation has also been suggested as a predictor for weight loss (Reed et al., 2016), and to be positively related to healthy diet and physical activity (Ng et al., 2012), but only in the short-term (Teixeira et al., 2012). The focus should be on supporting individuals to become autonomously motivated to achieve long-term weight loss goals.

### *Basic Psychological Needs*

According to SDT, autonomous motivation can be achieved if the three basic psychological needs of human beings are satisfied: *autonomy* (i.e., control over a situation, feelings of being in charge, and making decisions), *competence* (i.e., degree to which a person feels knowledgeable enough to affect change), and *relatedness* (i.e., sense of belonging, feeling connected, feeling cared for and valued) (Deci & Ryan, 2015). The perceived satisfaction of these needs was positively related to weight loss (Teixeira et al., 2012; Trief, Cibula, Delahanty, & Weinstock, 2017). An individual's perception of the satisfaction of these needs is only possible using a supportive environment. Support for autonomy can, for example, be realized by allowing individuals to feel in control of their weight loss by choosing their own goals and deciding how to achieve those goals, personalized to their specific circumstances (Silva et al., 2008). According to Deci & Ryan (2015) competence is

supported, for example, through positive feedback and challenges. Overweight or obese individuals will feel competent and be motivated in their weight loss journey if they actually see a weight change from engaging in weight loss behaviors. This change is achieved by enhancing competence through feedback, challenge, and knowledge (e.g., good vs. bad foods, how certain foods affect the body). Relatedness can be supported by making individuals feel that they have support for achieving weight loss and that others care about their weight loss journey.

### Literature Review Summary

According to the literature on the effectiveness of behavioral treatment interventions, effective weight loss (5-10%) is affected by goal-setting, self-monitoring, and counseling. Setting targets for food intake and physical activity provides goals to work towards. Self-monitoring assists with keeping track of those goals and counseling utilizes self-monitoring records to provide performance feedback and advice.

Calorie counter apps have been designed to incorporate the same features as behavioral treatment interventions. However, the literature indicates a gap in features to fully support effective weight loss. Research suggests that features supporting counseling and adherence are lacking. Furthermore, it was found that evidence-based behavior change techniques were not incorporated into their design. Behavior change techniques could be the vehicle to deliver counseling and to support motivation for adherence. Research findings indicated in the literature review suggest that for calorie counters to support effective weight loss, they need to incorporate features for self-monitoring, goal-setting, counseling, and to support motivation.

Motivation, according to the Self-Determination Theory, is achieved by satisfying our three basic psychological needs: autonomy, competence, and relatedness. SDT also posits that an environment that is conducive to perceived satisfaction of psychological needs will support continued motivation.

The following chapter discusses a design framework created to facilitate the design of calorie counters that will more effectively support weight loss. Chapter three also discusses the analysis approach of calorie counter apps, using the framework's functional requirements, to uncover the current state of calorie counter apps.

## CHAPTER THREE: METHODOLOGY

Chapter two reviewed literature on the factors of behavior treatment interventions that relate to effective weight loss. The literature reviewed indicated the ineffectiveness of calorie counter apps for supporting clinically significant weight loss (5-10% off baseline weight). However, their effectiveness seems to improve if coupled with behavioral intervention factors that contribute to effective weight loss, primarily counseling. According to the reviewed literature, users gradually discontinue calorie counter app use, suggesting the apps may not be designed for sufficient motivation to sustain engagement in weight loss behaviors. Incorporation of behavior change techniques, that promote motivation for behavior change (Gillison et al., 2019), seem to be lacking. Deci & Ryan's (1985) Self-Determination theory posits that motivation is maintained, and evolves, by satisfying our basic psychological needs (autonomy, competence, and relatedness).

This chapter describes the methodology used to analyze the features present in commercially available calorie counter apps to infer their capability in supporting users' motivation to achieve effective weight loss. This study used a content analysis study design to uncover gaps in the design features of calorie counters that seem to impede their effectiveness to support motivation for continued use.

The overarching research question that guided this study was:

*Do commercially available calorie counter apps include features for facilitating motivation and effective weight loss?*

It was expected that existing calorie counters lack features to support continuous motivation to engage in weight loss behaviors and thus to bring about significant weight loss; in particular, features for supporting or counseling users as they engage in weight loss behaviors.

## Analysis of Calorie Counter Applications

An analysis of the design of commercially available calorie counter apps was apt for understanding if calorie counters incorporate features that are likely to facilitate motivation and effective weight loss. A two-part approach was employed, which is depicted in Figure 2 along with theoretical foundations for the methodology.

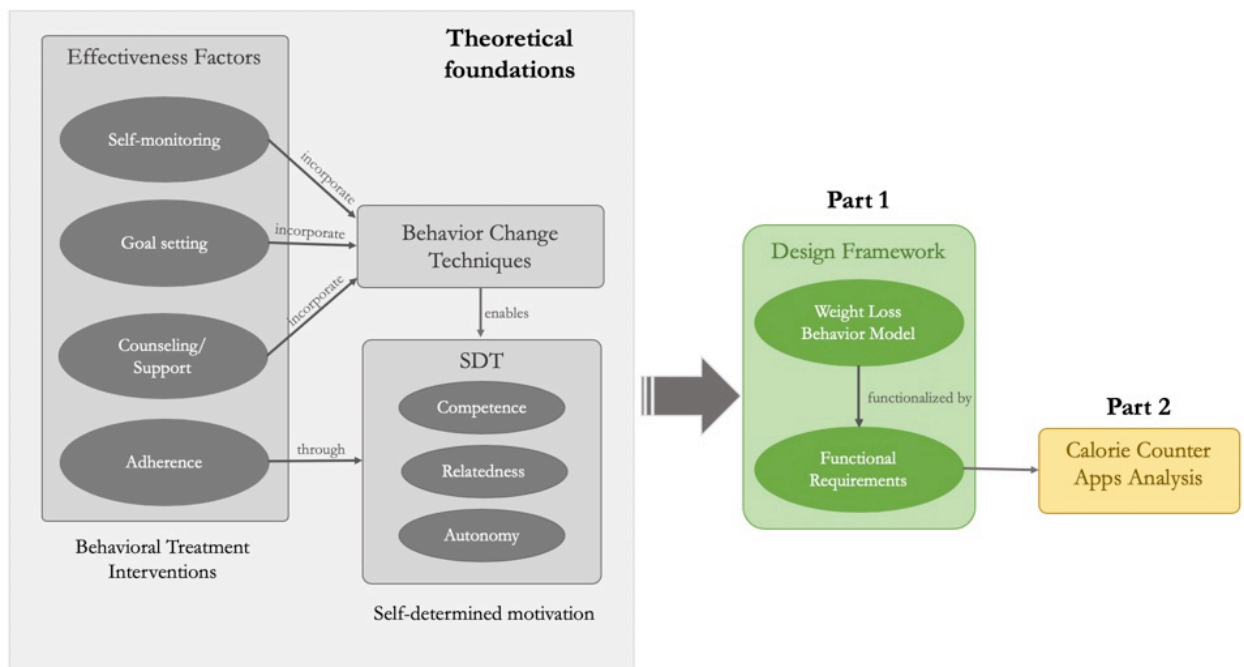


Figure 2. Theoretical Foundations and Content Analysis Methodology.

To conduct the content analysis, an analytical construct (Krippendorff, 2018), or comparator (Jake-Schoffman et al., 2017), was needed against which the app features were to be assessed. Part 1 consisted of the development of the analytical construct, a design framework aimed at promoting the design of effective and motivational calorie counters based on the literature review. Part 2



consisted of using the framework to evaluate the design of commercially available calorie counters.

The following sections describe the methods of Part 1 and Part 2 in detail.

### Part 1: Design Framework Development

Understanding how weight loss occurs and the factors that influence it was essential for the development of the design framework, which was used to evaluate the design of commercially available calorie counters. A conceptual model describing weight loss behaviors and their influencing factors were first created to underpin design requirements that are likely to lead to increased motivation and significant weight loss.

#### *Conceptualizing Weight Loss*

The first step in creating the conceptual model was to identify factors that have been associated with effective behavioral interventions for weight loss. A review of the literature indicated the factors presented in Table 2 as factors that are associated with effective weight loss interventions.

Table 2. Factors Associated with Effective Behavioral Interventions for Weight Loss

<b>Effectiveness Factor</b>	<b>Reference</b>
Comprehensive treatments (counseling, objectives, plus behavioral strategies).	(Hartmann-Boyce et al., 2014; Hassan et al., 2016; Nan et al., 2017)
Behavioral strategies associated with weight loss (e.g., goal-setting, self-monitoring, provision of instruction and information, goal review, and demonstrations)	(Dombrowski et al., 2012; Hankonen et al., 2014; Hartmann-Boyce et al., 2014; Lara et al., 2014; Samdal et al., 2017)
Intense personalized counseling	(Appel et al., 2011; Booth et al., 2014; Greaves et al., 2011; Hartmann-Boyce et al., 2014; LeBlanc et al., 2011)
Long duration treatments	(LeBlanc et al., 2011; Nan et al., 2017)

Secondly, how these factors interact to produce weight loss was considered by drawing on the foundations of behavioral weight loss interventions. In considering their interaction, the factors were condensed into the basic catalyzing behaviors necessary for effective weight loss: goal-setting, self-monitoring, support, and motivation. *Goal-setting* is defined as setting specific, measurable, and incremental goals to allow for the assessment of goal achievement in addition to the identification of problem areas and strategies to overcome them (Wadden & Foster, 2000). *Self-monitoring* is keeping a detailed daily record of food intake (e.g., what was eaten, caloric content, fat content), physical activity (e.g., duration and intensity), and weight (Butryn et al., 2011). *Support* includes elements that enable the acquisition of knowledge through the provision of personalized guidance to goal achievement. Support includes behavioral strategies such as nutrition or weight loss education and information, goal review, and demonstrations. *Motivation* refers to the satisfaction of the basic psychological needs (Deci & Ryan, 2015). Figure 3 illustrates the components listed above that make up the conceptual model leading to a cycle of weight loss behavior.



Figure 3. Weight Loss Behavior Model.

### *Weight Loss Behavior Cycle*

Weight loss is an incremental process brought about through the cyclical interaction of the basic weight loss behaviors (self-monitoring, goal-setting, support) as they influence each other, creating what can be referred to as, a “Weight Loss Behavior Cycle” (See Figure 3). Engaging in weight loss behaviors can be likened to the gradual development of skills to identify facilitators and barriers to weight loss success (Foster et al., 2005). Calorie counter users are adult learners who engage once they have objectives (i.e., goals), are guided through the process of achieving objectives (i.e., support), and understand why they need to engage in weight loss behaviors (i.e., data provided through self-monitoring) (Foster et al., 2005).

Goals initiating change and self-monitoring not only helps with initiation but also maintenance of change (Dombrowski et al., 2012). Calorie, physical activity, and weight goals (short-term and long-term) are set at the beginning of a weight loss journey and re-set throughout. Behaviors are self-monitored (daily/weekly) providing data for supporting the assessment of goal achievement. Supporting assessment of behaviors is necessary to uncover if an individual’s behavior has negatively, positively, or had no impact on progress towards goal achievement. Assessment may, for example, result in the identification of problems requiring a goal re-set or habit change, assist individuals in recognizing the relationship between self-monitored data and resulting goal progress, or identification of success factors, barriers, and behavior patterns. Support also includes the utilization of behavioral strategies such as providing feedback, nutrition or weight loss education, or reward based on behaviors and goal progress. Support is an integral part of the cycle as it is through support that the necessary skills to achieve weight loss are developed. Support must be continuous and personalized to an individual’s particular situation. Behavior change techniques are the “active

ingredients” necessary to bring about behavior change (Dombrowski et al., 2012) through cycle interaction.

### *Motivation*

Engagement in weight loss behaviors begins with motivation whether it be extrinsic or intrinsic. Drawing on Deci & Ryan’s (2015) SDT, which explains the conditions under which one engages in a certain behavior, the Weight Loss Behavior cycle is driven by motivation, and engagement in the cycle generates motivation. The cycle produces autonomy-supportive conditions which enable individuals to perceive that their three basic psychological needs, autonomy, competence, and relatedness, are being satisfied, generating autonomous motivation. The perceived satisfaction of these needs was positively related to weight loss (Teixeira et al., 2012; Trief et al., 2017). For effective and long-term maintenance of weight loss, research has suggested that autonomous motivation is key (Teixeira et al., 2012). In turn, motivation fuels the cycle through the internalization of skills and values. Internalization is the transformation of controlled behaviors to more autonomous behaviors (Deci & Ryan, 2015). The satisfaction of the three basic needs in the cycle increases autonomous motivation leading to gradual internalization of weight loss behaviors. The more one learns, the more one’s attitude towards healthy behaviors for weight loss changes, enabling increased intrinsic motivation.

### *Defining Design Requirements*

The Weight Loss Behavior Model presented in the previous section was used to guide the definition of design requirements shown in Table 3, Calorie Counter Application Functional Requirements.

Table 3. Calorie Counter Application Functional Requirements

<b>Weight loss behavior</b>	<b>CALO-RE BCT (Michie et al., 2011)</b>	<b>Motivational strategy (Gillison et al., 2019)</b>	<b>Psychological need satisfied</b>	<b>Functional Requirement</b>
<b>Goal-setting</b>	Goal-setting of behavior	Structure, Choice	Autonomy	GS 1. The app shall allow the user to set daily / weekly physical activity level goal. GS 2. The app shall allow the user to set daily / weekly calorie consumption goal. GS 3. The app shall allow the user to set daily / weekly calorie expenditure goal. GS 4. The app shall allow the user to set daily / weekly nutrient goals (e.g., macro nutrients).
	Goal-setting of outcome	Structure, Choice	Autonomy	GS 5. The app shall allow the user to set a target, weekly/and or monthly weight loss goal.
	Action planning	Structure, Choice	Autonomy	GS 6. The app shall allow the user to set time, duration, frequency, / intensity for physical activity based on behavioral goal. GS 7. The app shall allow the user to set calorie consumption goals per day of week / meal based on behavioral goal. GS 8. The app shall allow the user to set nutrient goals per day of week / per meal based on behavioral goal.
	Relapse prevention/Coping planning	Structure, Choice	Autonomy	GS 9. The app shall allow the user to set relapse triggers (e.g., a ‘red flag’ weight, no physical activity for a week, no self-monitoring for a few days etc.).
<b>Self-monitoring</b>	Prompt self-monitoring of behavior	Choice	Autonomy	SM 1. The app shall provide the user the means to daily/weekly input dietary intake (e.g., type of food, amount, calories) and physical activity (e.g., type of workout, calories burned, duration, intensity).
	Prompt self-monitoring of outcome	Choice	Autonomy	SM 2. The app shall provide the user the means to daily/weekly input weight measures (e.g. weight in lbs., BMI etc.).
	Teach to use prompts/cues	Choice	Autonomy	SM 3. The app shall allow the user to set reminders/notifications (may include time, day, context) to perform goal behaviors (or alternate behaviors that reduce incompatible behaviors).
	Prompt review of behavioral goals	Provide informational feedback	Competence	SM 4. The app shall provide the user with an overview of performance in relation to goals.
	Prompt rewards contingent on effort or progress towards behavior	Use of incentives	Competence	SM 5. The app shall provide the user rewards (verbal / tangible) for progress toward achieving behavior.

<b>Weight loss behavior</b>	<b>CALO-RE BCT (Michie et al., 2011)</b>	<b>Motivational strategy (Gillison et al., 2019)</b>	<b>Psychological need satisfied</b>	<b>Functional Requirement</b>
<b>Support</b>	Plan social support/social change	Encourage social support seeking	Relatedness	SUP 1. The app shall provide a means for the user to elicit social support from other app users (e.g., social community, groups, buddies etc.). SUP 2. The app shall advice the user to elicit social support from friends, family, / community outside of the app.
	Provide instruction on how to perform the behavior	Structure, Use of non-controlling language, Emphasize responsibility	Autonomy	SUP 3. The app shall provide advice to the user on how to eat (e.g., nutrition topics) and work out (e.g., types of physical activity, duration, frequency) for weight loss.
	Provide feedback on performance	Provide informational feedback, Use of non-controlling language	Competence, Autonomy	SUP 4. The app shall periodically (e.g., daily, weekly, / monthly) provide evaluative feedback (e.g., advise or suggestions) based on performance in relation to goals and behavior (e.g., when triggers go off). SUP 5. The app shall recommend re-setting goals based on performance.
	Model/Demonstrate the behavior	Structure, Use of non-controlling language	Autonomy	SUP 6. The app shall provide the user visual models/demonstrations on engaging in nutrition and physical activity behaviors (e.g., cooking class, demonstration of preparing a meal, demonstration of a workout).
	Prompt practice	Structure, Use of non-controlling language	Autonomy	SUP 7. The app shall prompt/remind/notify the user to input dietary intake and physical activity. SUP 8. The app shall prompt the user to input weight measurements. SUP 9. The app shall prompt/remind/notify the user to perform weight loss behaviors.
	Set graded tasks	Provide optimal challenge	Competence	SUP 10. The app shall provide the user with a sequence of personalized incremental behavioral tasks until the target behavior is achieved.
	Barrier identification/problem solving	Barrier identification	Competence	SUP 11. The app shall prompt the user to identify barriers preventing them from eating healthy / working out. SUP 12. The app shall provide suggestions to the user on how to overcome barriers (e.g., restructuring the environment, working out with a friend).
	Provide information on the consequences of behavior to the individual	Provide information, Use of non-controlling language	Competence, Autonomy	SUP 13. The app shall provide tailored information to the user based on positive/negative behavior.
	Use of follow up prompts	Provide support and encouragement, Involvement	Competence, Relatedness	SUP 14. The app shall push notifications (e.g., interactive questions) to the user if they have been inactive for a while to follow up on progress or for encouragement.

The design requirements are to be used as criteria for evaluating the design of commercially available calorie counter applications. The requirements were defined by aligning the basic weight loss behaviors, behavior change techniques from the CALO-RE taxonomy (Michie et al., 2011), motivational strategies (Gillison et al., 2019), and the particular psychological need that is satisfied. They are represented as the column headings in Table 3. The Weight Loss Behavior Model was used to underpin the definition of design requirements to ensure support of the interaction between weight loss behaviors and motivation to facilitate effective weight loss. In other words, the defined design requirements should support both effectiveness and motivation. Column 1 in Table 3 is comprised of the weight loss behaviors: goal-setting, self-monitoring, and support.

According to the Weight Loss Behavior Model, the weight loss behaviors interact with each other through the incorporation of behavior change techniques, which serve as “active ingredients” to ensure engagement in behaviors to bring about behavior change. Behavior change techniques from the CALO-RE taxonomy that are associated with positive change in dietary, physical activity, and weight loss outcomes (see Appendix A) are in column 2, aligned to the weight loss behaviors. The conceptual model represented motivation as the driving force of the interaction between weight loss behaviors (goal-setting, self-monitoring, and support). These behaviors, in turn, also promote motivation for behavior change. According to Self Determination Theory, to produce motivation, and thus internalize weight loss behaviors for long-term maintenance, an environment conducive to the experience of one or more of the three basic psychological needs (autonomy, competence, relatedness) should be created (Deci & Ryan, 2015; Williams, Cox, & Ryan, 1998). In considering the creation of an environment conducive to satisfaction of needs and drawing on the literature review, motivational strategies that were indicated as having an impact on the satisfaction of each psychological need were aligned to the weight loss behaviors and behavior change techniques. Table

3, column 3 presents the motivational strategies (Gillison et al., 2019) that would most likely facilitate engagement in weight loss behaviors and satisfy specific psychological needs (column 4), thus producing motivation. The functional requirements defined, are listed in Table 3 column 5 as GS- representing goal-setting requirements, SM- self-monitoring requirements, and SUP- support requirements.

#### *Goal-setting Functional Design Requirements*

Goal-setting is defined as setting specific, measurable, and incremental goals to allow for the assessment of goal achievement. Setting goals not only incites individuals to work towards changing behaviors for weight loss, but it also highlights problem areas when goals have not been achieved. When problem areas or barriers have been identified, strategies can be implemented to overcome them.

Goal-setting functional design requirements describe setting calorie, physical activity, and weight goals (short-term and long-term). Goal-setting requirements can be regarded as planning for weight loss. Behavioral goals and outcome goals should be defined, actions that are going to be taken to achieve those goals should be defined, and a threshold should be set to assist with staying the course.

#### *Self-Monitoring Functional Design Requirements*

Self-monitoring is keeping a detailed daily record of food intake (e.g., what was eaten, caloric content, fat content), physical activity (e.g., duration and intensity), and weight (Butryn et al., 2011). Self-monitoring is important as it provides data to assist in understanding the need for



engaging in weight loss behaviors and goal progress. Goals initiate change and self-monitoring not only helps with initiation but also maintenance of change (Dombrowski et al., 2012).

Self-monitoring functional design requirements focuses on self-monitoring behavior and outcomes, encourages self-monitoring, allows for goal review, and provides reward based on the performance data.

### *Support Functional Design Requirements*

Support includes factors that enable the acquisition of knowledge through the provision of personalized guidance for goal achievement. The knowledge and skills necessary to achieve weight loss are delivered through support. Support includes elements such as feedback, education, information delivery, and performance assessment. Assessment is paramount for weight loss as it reveals impacts on goal progress whether it be positive, negative, or no impact.

Support functional requirements include planning and eliciting social support for the weight loss journey, providing performance feedback, providing incremental tasks for achieving goals, problem solving, providing information, instruction and demonstration, reminding users to engage in weight loss behaviors, and encouraging users to self-monitor and engage in weight loss behaviors.

### Part 2: Procedure for Analysis of Calorie Counter Applications

In order to performing the content analysis on appropriate calorie counter app candidates, the procedure described below, along with criteria listed in Table 4, was used to select a representative sample. Calorie counter apps on the iOS platform were targeted for this analysis. 14 apps were selected for download and analysis including the description and feature inclusion. Findings were reported with checkmarks for meeting functional requirements.

### *Inclusion and Exclusion Criteria*

The analysis targeted calorie counter apps that were available for download on the iOS platform. The selection of apps to include in the sample for this analysis, aimed to focus on the most popular calorie counter apps. This selection was done to obtain a sample of apps that were most likely to be downloaded.

Table 4 summarizes the inclusion criteria for this analysis. Calorie counter apps were selected if they were 1) on the top ranking (based on user downloads and ratings) iOS apps chart in the Health and Fitness category. Apps targeted for analysis were also 2) free for download and did not require in-app purchases for using goal-setting and tracking features. Furthermore, apps were included in the analysis if they 3) were considered to be calorie counters, 4) focused on weight loss, and 5) did not require integration with another app for setting goals or tracking diet and physical activity.

Table 4. Inclusion Criteria

<b>Inclusion Criteria</b>	<b>Description</b>
Free	Free for download, including the use of goal-setting and tracking features.
Popular	Top ranking in terms of downloads and user ratings
Calorie counter	Users can set goals, and track food and physical activity.
Weight loss	Apps that specifically target weight loss.
Standalone	Setting goals, tracking diet and physical activity does not require integration to another app.

Apps were excluded if they focused on specific types of diets and if they were apps designed for specific diet programs such as Weight Watchers. Apps were also excluded from analysis if they only focused on tracking physical activity.

### *Selection Strategy*

App Annie (App Annie, 2019), a top mobile analytics and market data platform, was used to identify the most popular iOS apps in the Health and Fitness Category in the U.S. Results were filtered by selecting “Free”, “iOS” as the platform, “United States” as country, “Health and Fitness” as the category, and “All Apps” to include apps that provide in app purchases and those that do not. The apps in the Health and Fitness category included various types of health-related apps such as for physical fitness, sleep, psychological health, and blood pressure maintenance. The top charts list in the iOS Health and Fitness category consisted of 500 apps. The App Annie “iOS Top Charts” list was accessed between August 14<sup>th</sup> and 16<sup>th</sup> 2019.

### *Screening*

The 500 apps on the top charts list were screened against the inclusion and exclusion criteria based on app descriptions and screenshots. Descriptions and screenshots were not reviewed for particular apps where it was evident from the name that the app focused on a health topic other than counting calories. Each app that met the inclusion criteria was downloaded for analysis.

### *Analysis*

The apps that met the inclusion criteria were downloaded to an iPhone 8 running iOS 12.4.1. Each functional requirement defined in Table 3, was compared to the features present in the downloaded apps. A checkmark documented if an app feature satisfied a requirement. To get a checkmark, the feature present in the app had to match the requirement precisely. If an app feature partially met the requirement this was not documented with a checkmark. For example, for the requirement “SUP (Support) 5. The app shall recommend re-setting goals based on performance”

an app would not receive a checkmark if the user is merely allowed to re-set his or her goals. The requirement states that it is the app that should recommend to the user to re-set goals based on their performance.

### Methodology Summary

Chapter 3 described the methods used to create a design framework based on the literature review, consisting of the Weight Loss Behavior Model that led to the development of functional requirements aligning to identified weight loss factors. This chapter also covered the procedure for obtaining a sample of calorie counter apps for analysis, in addition to the procedure for analyzing calorie counter apps using the functional requirements. Chapter 4 reports on the findings of the analysis conducted on the sampled calorie counter apps.

## CHAPTER FOUR: FINDINGS

Chapter 3 described the methodology that was employed to answer the research question: *“Do commercially available calorie counter apps include features for facilitating motivation and effective weight loss?”*

Chapter 3 discussed the creation of a design framework for analyzing calorie counter apps. The framework consisted of a model, Weight Loss Behavior Model, that was developed based on the literature review and a set of functional design requirements that were defined based on the model. The model described how weight loss occurs through the interaction of weight loss behaviors (self-monitoring, goal-setting, support) and motivation. Functional requirements for the design of calorie counter apps that support weight loss were defined based on that model. The requirements were defined by aligning the weight loss behaviors, behavior change techniques, motivational strategies, and the Self Determination Theory’s (Deci & Ryan, 1985) basic psychological needs. Chapter 3 also described the procedure for obtaining a sample of calorie counter apps and the analysis comparing app features to the functional requirements.

This chapter presents the results of the analysis. Presented first are the results of the sampling process followed by the results of the analysis using the functional design requirements. Also discussed are the limitations and research implications.

### Sampling Findings

Figure 4 provides a summary of the sampling findings. A total of 500 apps were listed after filtering App Annie’s iOS Top Chart list to display apps that were free, available in the U.S. app store, in the Health and Fitness category, and with and without in-app purchasing. The apps were then screened based on their title, description, and screenshot against the inclusion criteria.

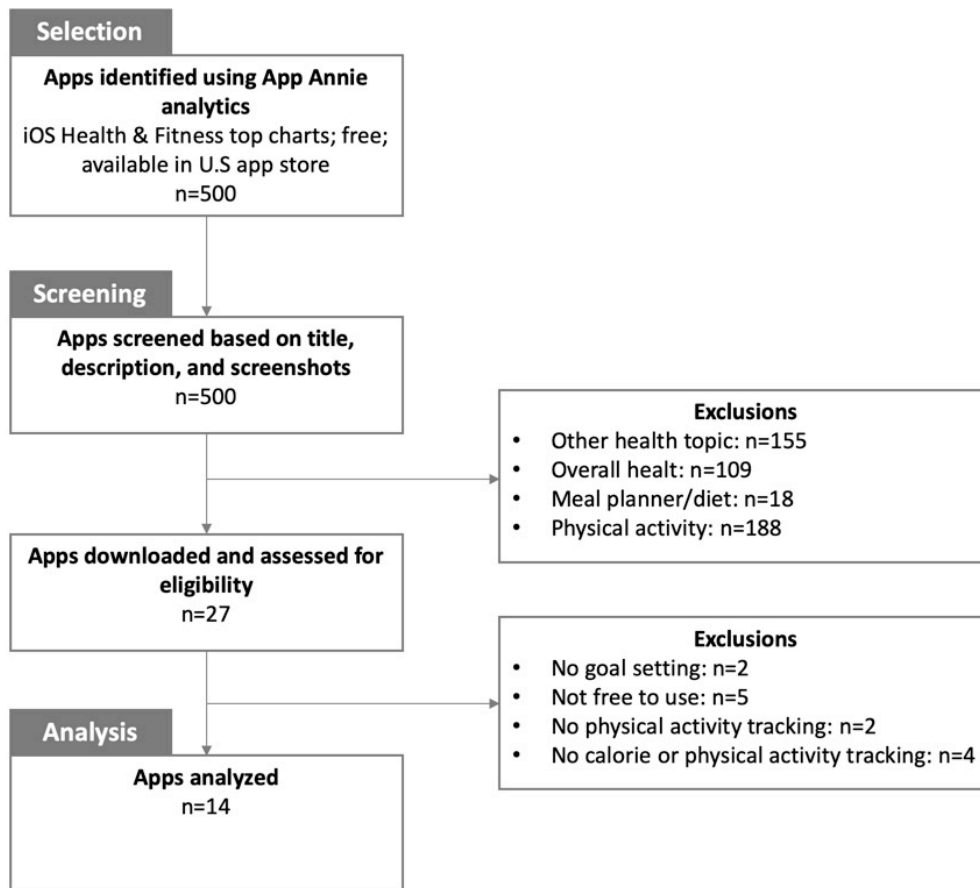


Figure 4. Summary of the Selection Process of Calorie Counter Apps for Analysis

Apps on the list were excluded because they covered health topics other than weight loss (e.g., sleep, meditation, psychological health, pregnancy, period trackers etc.), overall health topics (e.g., health care management, heart rate trackers, water intake trackers etc.), meal planners or apps just focusing on a particular diet (e.g., keto diet), and apps targeting physical activity. After screening a total of 27 apps that appeared to be eligible for analysis, the sample apps were downloaded. After assessing the apps for eligibility, a total of 13 apps were excluded because apps did not include goal-setting features, were not free to use, users were unable to track exercise, or users were unable to

track both exercise and diet. A total of 14 apps were retained for comparison against the functional requirements. These results are presented in the following section.

### Analysis Findings

The apps selected for analysis using the functional design requirements are listed in Table 5.

The features of each app were compared against the functional design requirements.

Table 5. Calorie Counter Apps Selected for Analysis

<b>Calorie Counter App</b>	<b>Star Ratings (out of 5)</b>	<b>Number of Ratings</b>
Fitbit (Fitbit Inc., 2011)	4.2	73,542
MyFitnessPal (UnderArmour Inc., 2009)	4.7	805,822
Noom (Noom Inc., 2010)	4.6	135,621
Lose It! (FitNow Inc., 2008)	4.7	343,959
MyPlate Calorie Counter (Leaf Group Ltd., n.d.)	4.6	18,348
Foodvisor Calorie Counter (Foodvisor, n.d.)	4.5	2,484
My Diet Coach – Weight Loss (InspiredApps, n.d.)	4.6	15,028
Yazio Diet & Food Tracker (YAZIO GmbH, n.d.)	4.6	10,335
Calorie Counter by FatSecret (FatSecret, n.d.)	4.7	3,414
Calorie Counter – MyNetDiary (MyNetDiary Inc., n.d.)	4.7	5,982
Fooducate Diet & Nutrition (Fooducate Ltd., 2010)	4.7	46,069
Cronometer – Nutrition Tracker (Cronometer Software Inc., 2011)	4.7	4,792
ControlMyWeight (CalorieKing, 2013)	4.6	10,567
Nutra Check Calorie Counter (NutraTech Ltd, n.d.)	4.7	3,100

If an app included the feature listed in the functional design requirements, this was documented with a checkmark. Tables 6 through 11 present the findings of the analysis. As the functional requirements were defined based on the weight loss behaviors from the Weight Loss

Behavior Model, the tables report the findings based on the three weight loss behaviors: self-monitoring, goal-setting, and support.

### *Goal-setting*

Goal-setting functional design requirements were used to analyze the inclusion of goal-setting features in calorie counter apps. Table 6 and 7 presents the results for evaluation of goal-setting features within the most popular calorie counter applications on the iOS platform. The apps analyzed included between six to eight of the nine goal-setting functional requirements ( $M=7.5$ ,  $SD=0.65$ ). The requirements most often included were: setting an exercise level goal (GS1) (93%), setting an overall calorie intake goal (GS2) (100%), setting daily or weekly calorie expenditure goals (GS3) (79%), setting nutrient goals (GS4) (93%), setting a weight loss goal (GS5) (100%), setting time, duration, frequency or intensity of exercise (GS6) (100%), setting calorie consumption goal per day / meal based on overall calorie goal (GS7) (93%), and setting nutrient goals per day / meal based on overall nutrient goal (GS8) (93%). None of the apps that were analyzed included setting relapse trigger goals for relapse prevention (GS9).



Table 6. Analysis Findings for Goal-setting 1

	Fitbit	MyFitnessPal	Noom	Lose It!	MyPlate Calorie Counter	Foodvisor Calorie Counter	My Diet Coach – Weight Loss
GS 1. The app shall allow the user to set daily / weekly physical activity level goal.	✓	✓	✓	✓	✓	✓	✓
GS 2. The app shall allow the user to set daily / weekly calorie consumption goal.	✓	✓	✓	✓	✓	✓	✓
GS 3. The app shall allow the user to set daily / weekly calorie expenditure goal.	✓	✓	X	✓	X	X	✓
GS 4. The app shall allow the user to set daily / weekly nutrient goals (e.g., macro nutrients).	X	✓	✓	✓	✓	✓	✓
GS 5. The app shall allow the user to set a target, weekly/and or monthly weight loss goal.	✓	✓	✓	✓	✓	✓	✓
GS 6. The app shall allow the user to set time, duration, frequency, / intensity for physical activity based on behavioral goal.	✓	✓	✓	✓	✓	✓	✓
GS 7. The app shall allow the user to set calorie consumption goals per day of week / meal based on behavioral goal.	X	✓	✓	✓	✓	✓	✓
GS 8. The app shall allow the user to set nutrient goals per day of week / per meal based on behavioral goal.	X	✓	✓	✓	✓	✓	✓
GS 9. The app shall allow the user to set relapse triggers (e.g., a ‘red flag’ weight, no physical activity for a week, no self-monitoring for a few days etc.).	X	X	X	X	X	X	X

	Fitbit	MyFitnessPal	Noom	Lose It!	MyPlate Calorie Counter	Foodvisor Calorie Counter	My Diet Coach – Weight Loss
<b>Total amount of GS requirements</b>	5 (56%)	8 (88%)	7 (77%)	8 (88%)	7 (77%)	7 (77%)	8 (88%)

Table 7. Analysis Findings for Goal-setting 2

	Yazio Diet & Food Tracker	Calorie Counter by FatSecret	Calorie Counter - MyNetDiary	Fooducate Diet & Nutrition	Cronometer – Nutrition Tracker	ControlMyWeight	Nutra Check Calorie Counter
GS 1. The app shall allow the user to set daily / weekly physical activity level goal.	✓	✓	✓	✓	✓	X	✓
GS 2. The app shall allow the user to set daily / weekly calorie consumption goal.	✓	✓	✓	✓	✓	✓	✓
GS 3. The app shall allow the user to set daily / weekly calorie expenditure goal.	✓	✓	✓	✓	✓	✓	✓
GS 4. The app shall allow the user to set daily / weekly nutrient goals (e.g., macro nutrients).	✓	✓	✓	✓	✓	✓	✓
GS 5. The app shall allow the user to set a target, weekly/and or monthly weight loss goal.	✓	✓	✓	✓	✓	✓	✓
GS 6. The app shall allow the user to set time, duration, frequency, / intensity for physical activity based on behavioral goal.	✓	✓	✓	✓	✓	✓	✓
GS 7. The app shall allow the user to set calorie consumption	✓	✓	✓	✓	✓	✓	✓

	Yazio Diet & Food Tracker	Calorie Counter by FatSecret	Calorie Counter - MyNetDiary	Fooducate Diet & Nutrition	Cronometer – Nutrition Tracker	ControlMyWeight	Nutra Check Calorie Counter
goals per day of week / meal based on behavioral goal.							
GS 8. The app shall allow the user to set nutrient goals per day of week / per meal based on behavioral goal.	✓	✓	✓	✓	✓	✓	✓
GS 9. The app shall allow the user to set relapse triggers (e.g., a ‘red flag’ weight, no physical activity for a week, no self-monitoring for a few days etc.).	X	X	X	X	X	X	X
<b>Total amount of GS requirements</b>	<b>8 (88%)</b>	<b>8 (88%)</b>	<b>8 (88%)</b>	<b>8 (88%)</b>	<b>8 (88%)</b>	<b>7 (77%)</b>	<b>8 (88%)</b>

Overall, these findings suggest that popular calorie counter apps include features to support users in setting goals for weight loss. Findings indicate that calorie counters include features that allow users to set behavioral goals, outcome goals, and set a plan for what they would do to achieve those goals. Allowing users to set these types of goals provide structure for their weight loss journey and gives them control, through choice, of their own weight loss. Features for behavioral goals, outcome goals, and action planning facilitates perceived autonomy which promotes motivation. However, findings also suggest that apps do not include features for relapse prevention. Such features would allow users to devise strategies to avoid or manage identified situations in which the changed behavior may not be maintained. Lack of this feature suggests that motivation and successful weight loss may be affected. Weight loss behaviors may be initiated but not maintained long-term.

### *Self-Monitoring*

Self-monitoring functional requirements were compared to popular iOS calorie counter apps to assess the inclusion of self-monitoring features. The following tables, table 8 and 9, presents the results for the evaluation of self-monitoring within the most popular calorie counter applications on the iOS platform. The apps analyzed included between two to four of the five self-monitoring functional requirements ( $M=3.5$ ,  $SD=0.76$ ). The requirements most often included were: self-monitoring of diet and physical activity (SM1) (100%), self-monitoring weight (SM2) (100%), reviewing performance in relation to goals (SM4) (86%). The requirements that were included the least were: receiving rewards based on performance (SM5) (43%) and allowing users to set reminders to engage in goal behaviors or alternate behaviors (SM3) (21%).

Table 8. Analysis Findings for Self-Monitoring 1

	Fitbit	MyFitnessPal	Noom	Lose It!	MyPlate Calorie Counter	Foodvisor Calorie Counter	My Diet Coach – Weight Loss
SM 1. The app shall provide the user the means to daily/weekly input dietary intake (e.g., type of food, amount, calories) and physical activity (e.g., type of workout, calories burned, duration, intensity).	✓	✓	✓	✓	✓	✓	✓
SM 2. The app shall provide the user the means to daily/weekly input weight measures (e.g. weight in lbs., BMI etc.).	✓	✓	✓	✓	✓	✓	✓
SM 3. The app shall allow the user to set reminders/notifications (may	X	X	X	X	✓	X	✓

include time, day, context) to perform goal behaviors (or alternate behaviors that reduce incompatible behaviors).								
SM 4. The app shall provide the user with an overview of performance in relation to goals.	✓	✓	✓	✓	✓	✓	✓	✓
SM 5. The app shall provide the user rewards (verbal / tangible) for progress toward achieving behavior.	✓	✓	✓	✓	X	X		✓
<b>Total amount of SM requirements</b>	<b>4 (80%)</b>	<b>4 (80%)</b>	<b>4 (80%)</b>	<b>4 (80%)</b>	<b>4 (80%)</b>	<b>3 (60%)</b>	<b>4 (80%)</b>	

Table 9. Analysis Findings for Self-Monitoring 2

	Yazio Diet & Food Tracker	Calorie Counter by FatSecret	Calorie Counter – MyNetDiary	Fooducate Diet & Nutrition	Cronometer – Nutrition Tracker	ControlMyWeight	Nutra Check Calorie Counter
SM 1. The app shall provide the user the means to daily/weekly input dietary intake (e.g., type of food, amount, calories) and physical activity (e.g., type of workout, calories burned, duration, intensity).	✓	✓	✓	✓	✓	✓	✓
SM 2. The app shall provide the user the means to daily/weekly input weight measures (e.g. weight in lbs., BMI etc.).	✓	✓	✓	✓	✓	✓	✓
SM 3. The app shall allow the user to set reminders/notifications (may include time, day, context) to perform goal behaviors (or alternate behaviors that reduce incompatible behaviors).	X	X	X	X	X	X	✓

	Yazio Diet & Food Tracker	Calorie Counter by FatSecret	Calorie Counter – MyNetDiary	Fooducate Diet & Nutrition	Cronometer – Nutrition Tracker	ControlMyWeight	Nutra Check Calorie Counter
SM 4. The app shall provide the user with an overview of performance in relation to goals.	✓	✓	✓	X	X	✓	✓
SM 5. The app shall provide the user rewards (verbal / tangible) for progress toward achieving behavior.	✓	✓	X	X	X	X	X
<b>Total amount of SM requirements</b>	<b>4 (80%)</b>	<b>4 (80%)</b>	<b>3 (60%)</b>	<b>2 (40%)</b>	<b>2 (40%)</b>	<b>3 (60%)</b>	<b>4 (80%)</b>

In general, findings suggest that popular calorie counters on the iOS platform, include the majority of self-monitoring requirements. Findings indicate that these calorie counters include features for self-monitoring behaviors and outcomes, and to encourage users to monitor their progress. Self-monitoring behaviors and outcomes give the users a sense of control over their weight loss which facilitates perceived autonomy. Furthermore, encouraging users to monitor their progress by reviewing the extent to which set goals were achieved, and revising goals or means as necessary, promotes competence and thus motivation to continue engaging in weight loss behaviors and thus achieve weight loss. However, findings indicate that apps are less likely to feature a means to teach users to identify environmental cues that can be used as reminders to perform a desired behavior, or an alternate behavior to reduce an undesired behavior. Lack of this feature may not only negatively affect a users’ perceived autonomy but also competence. Findings also indicate that apps may not include features that encourage users with rewards for attempts at achieving behavioral goals. This lack of cues also may have a negative impact on a user’s perceived competence.

### *Support*

Support functional requirements were compared to popular iOS calorie counter apps to assess the inclusion of support features. Table 10 and 11 present the results for the evaluation of support within the most popular calorie counter applications on the iOS platform. The apps analyzed included between 1-12 of the 14 support functional requirements ( $M=5.36$ ,  $SD=2.79$ ). The requirements most often included were: providing users with advice on how to eat and work out to achieve their weight loss goals (SUP3) (86%), providing evaluative feedback on performance (SUP4) (79%), recommending the user reset their goals based on performance (SUP5)(57%), providing a means to help users elicit social support from other app users (SUP1) (57%), and providing a model of ideal diet and physical activity behaviors for the user (SUP6) (57%). The least frequent requirements included in apps were: prompting users to engage in weight loss behaviors by reminding users to self-monitor diet and physical activity (SUP7) (43%), reminding users to perform weight loss behaviors (SUP9) (43%), reminding users to step on the scale to record their weight (SUP8) (43%), assisting the user in identifying barriers to success (SUP11) (29%), providing the user with tailored information on the consequences of their behavior (SUP13) (29%), making suggestions to the user on how to overcome barriers (SUP12) (14%), providing personalized incremental tasks to achieve particular behaviors (SUP10) (7%), and advising users to elicit support from friends or family members (SUP2) (7%). None of the 14 apps included a feature to ‘check in’ with the user if they have been inactive for a while (SUP14).

Table 10. Analysis Findings for Support 1

	Fitbit	MyFitnessPal	Noom	Lose It!	MyPlate Calorie Counter	Foodvisor Calorie Counter	My Diet Coach – Weight Loss
SUP 1. The app shall provide a means for the user to elicit social support from other app users (e.g., social community, groups, buddies etc.).	✓	✓	✓	✓	✓	X	X
SUP 2. The app shall advise the user to elicit social support from friends, family, / community outside of the app.	X	X	X	X	X	X	X
SUP 3. The app shall provide advice to the user on how to eat (e.g., nutrition topics) and work out (e.g., types of physical activity, duration, frequency) for weight loss.	X	✓	✓	✓	✓	✓	✓
SUP 4. The app shall periodically (e.g., daily, weekly, / monthly) provide evaluative feedback (e.g., advise or suggestions) based on performance in relation to goals and behavior (e.g., when triggers go off).	X	✓	✓	✓	X	✓	✓
SUP 5. The app shall recommend re-setting goals based on performance.	X	X	✓	X	X	✓	✓
SUP 6. The app shall provide the user visual models/demonstrations on engaging in nutrition and physical activity behaviors (e.g., cooking class, demonstration of preparing a meal, demonstration of a workout).	✓	✓	✓	✓	✓	X	X
SUP 7. The app shall prompt/remind/notify the user	X	✓	✓	✓	✓	X	✓



	Fitbit	MyFitnessPal	Noom	Lose It!	MyPlate Calorie Counter	Foodvisor Calorie Counter	My Diet Coach – Weight Loss
to input dietary intake and physical activity.							
SUP 8. The app shall prompt the user to input weight measurements.	X	✓	✓	✓	✓	X	✓
SUP 9. The app shall prompt/remind/notify the user to perform weight loss behaviors.	X	✓	✓	✓	✓	X	✓
SUP 10. The app shall provide the user with a sequence of personalized incremental behavioral tasks until the target behavior is achieved.	X	X	✓	X	X	X	X
SUP 11. The app shall prompt the user to identify barriers preventing them from eating healthy / working out. out with a friend).	X	X	✓	X	X	✓	✓
SUP 12. The app shall provide suggestions to the user on how to overcome barriers (e.g., restructuring environment, working out)	X	X	✓	X	X	X	X
SUP 13. The app shall provide tailored information to the user based on positive/negative behavior	X	X	✓	X	X	✓	X
SUP 14. The app shall push notifications (e.g., interactive questions) to the user if they have been inactive for a while to follow up on progress or for encouragement.	X	X	X	X	X	X	X
<b>Total amount of SUP requirements</b>	<b>2 (14%)</b>	<b>7 (50%)</b>	<b>12 (86%)</b>	<b>7 (50%)</b>	<b>6 (43%)</b>	<b>5 (36%)</b>	<b>5 (36%)</b>

Table 11. Analysis Findings for Support 2

	Yazio Diet & Food Tracker	Calorie Counter by FatSecret	Calorie Counter - MyNetDiary	Fooducate Diet & Nutrition	Cronometer – Nutrition Tracker	ControlMyWeight	Nutra Check Calorie Counter
SUP 1. The app shall provide a means for the user to elicit social support from other app users (e.g., social community, groups, buddies etc.).	X	X	✓	X	✓	X	✓
SUP 2. The app shall advise the user to elicit social support from friends, family, / community outside of the app.	X	X	X	X	X	X	✓
SUP 3. The app shall provide advice to the user on how to eat (e.g., nutrition topics) and work out (e.g., types of physical activity, duration, frequency) for weight loss.	✓	✓	✓	✓	X	✓	✓
SUP 4. The app shall periodically (e.g., daily, weekly, / monthly) provide evaluative feedback (e.g., advise or suggestions) based on performance in relation to goals and behavior (e.g., when triggers go off).	✓	✓	✓	✓	X	✓	✓
SUP 5. The app shall recommend re-setting goals based on performance.	✓	✓	✓	✓	X	X	✓
SUP 6. The app shall provide the user visual models/demonstrations on engaging in nutrition and physical activity behaviors (e.g., cooking class, demonstration of preparing a meal, demonstration of a workout).	✓	X	✓	✓	X	X	X

	Yazio Diet & Food Tracker	Calorie Counter by FatSecret	Calorie Counter - MyNetDiary	Fooducate Diet & Nutrition	Cronometer – Nutrition Tracker	ControlMyWeight	Nutra Check Calorie Counter
SUP 7. The app shall prompt/remind/notify the user to input dietary intake and physical activity.	X	X	✓	X	X	X	X
SUP 8. The app shall prompt the user to input weight measurements.	X	X	✓	X	X	X	X
SUP 9. The app shall prompt/remind/notify the user to perform weight loss behaviors.	X	X	✓	X	X	X	X
SUP 10. The app shall provide the user a sequence of personalized incremental behavioral tasks until the target behavior is achieved.	X	X	X	X	X	X	X
SUP 11. The app shall prompt the user to identify barriers preventing them from eating healthy / working out. out with a friend).	X	✓	X	X	X	X	X
SUP 12. The app shall provide suggestions the user on how to overcome barriers (e.g., restructuring environment, working	X	✓	X	X	X	X	X
SUP 13. The app shall provide tailored information to the user based on positive/negative behavior	X	✓	X	✓	X	X	X
SUP 14. The app shall push notifications (e.g., interactive questions) to the user if they have been inactive for a while to follow up on progress or for encouragement.	X	X	X	X	X	X	X

	Yazio Diet & Food Tracker	Calorie Counter by FatSecret	Calorie Counter - MyNetDiary	Fooducate Diet & Nutrition	Cronometer – Nutrition Tracker	ControlMyWeight	Nutra Check Calorie Counter
<b>Total amount of SUP requirements</b>	4 (29%)	6 (43%)	8 (57%)	5 (36%)	1 (7%)	2 (14%)	5 (36%)

Overall, findings indicate that many apps do not include support requirements. Results suggest that apps available on the iOS market do not do much to support users throughout their weight loss journey. This finding is concerning because it is through support that the necessary skills to achieve weight loss are developed. A lack of support translates to apps that do not facilitate continued motivation to engage in weight loss behaviors, and that are thus ineffective for promoting weight loss success. Findings suggest that calorie counters do include features for providing feedback on performance and providing instruction on how to perform weight loss behaviors. These features promote autonomy and competence suggesting that calorie counters can motivate users to engage in weight loss behaviors. However, the fact that the majority of the support features are lacking indicates that calorie counters may not support motivation for effective weight loss.

The lack of support for motivation and effective weight loss is indicated by findings suggesting that apps do a poor job of helping users to identify barriers to success and assist with overcoming these barriers. This finding may affect a user's sense of competence. An individual who is trying to lose weight, but cannot, and does not know how to be successful, may become discouraged and give up. Besides that barrier, if a user does not know what he or she is doing wrong, it becomes difficult to lose weight. Furthermore, supporting the assessment of behaviors is necessary to uncover if an individual's behavior has negatively, positively, or had no impact

on progress towards goal achievement. Results indicate that features for assessing behaviors are lacking which may negatively affect perceived competence. Competence may be affected by not informing users of the consequences of their behaviors, not giving them incremental goals, and not following up if they have been inactive for a while does nothing to support a user's weight loss efforts. Findings also seem to indicate that apps may not include features that prompt users to reset their goals depending on their performance. This barrier may also affect competence as he or she may be trying to lose weight based on goals that do not fit for example their lifestyle, body composition, etc. Support must be continuous and personalized to an individual's particular situation. Another gap that is indicated by the results is not encouraging the user to elicit social support. This lack of social support directly affects the perceived satisfaction of relatedness. Social support provides the human element amidst the technology and may increase a sense of accountability that the app may not be able to provide.

## Discussion

This study analyzed popular calorie counter apps on the iOS platform for the inclusion of goal-setting, self-monitoring, and support functional requirements. The inclusion of functional design requirements helped infer if popular commercially available calorie counter apps incorporate goal-setting, self-monitoring, and support features to support motivation for effective weight loss.

Analysis findings suggest that calorie counters include features for goal-setting and self-monitoring. The finding indicating the incorporation of self-monitoring and goal-setting features is in accordance with research stating that goal-setting and self-monitoring are the most common features included in calorie counter apps (Azar et al., 2013; Bardus et al., 2014; Payne et al., 2015).

A major gap indicated by this study's analysis is the lack of personalized support calorie counters offer to users for effective weight loss. This gap is concerning because it is through support that the necessary skills to achieve weight loss are developed. Intense and continued personalized weight loss counseling may be essential for helping overweight and obese individuals lose clinically significant weight (Tsai et al., 2018).

It is pivotal that the three weight loss strategies interact to achieve continued progress to effective weight loss. Users should have goals (goal-setting), know how to identify facilitators and barriers to achieving those goals (support), be aware of progress to goals (self-monitoring), and based on goal progress understand what and how to change their behavior (self-monitoring, support) (Foster et al., 2005). The findings suggest the lack of support features may explain why calorie counters are ineffective for facilitating weight loss.

Firstly, this study's analysis suggests that apps fall short in facilitating a plan for when engagement in weight loss behaviors is neglected. Users are not able to set a plan in case of relapse. This inability to support a user's plan may be a contributing factor to the lack of motivation for continued app use. The lack of relapse prevention features may cause a break down in the Weight Loss Behavior Cycle, in that a user's perceived autonomy is negatively affected, which subsequently negatively affects the internalization of skills and values. Preventing relapse supports continued engagement in weight loss behaviors as it prevents one from returning to undesirable behaviors. Allowing users to set a plan to keep on track, may be a step towards facilitating weight loss success. Secondly, app reminders or notifications can serve as cues to incite particular behaviors. Findings suggest that users may not engage in or abstain from engaging in certain behaviors if they are not being encouraged to do so. This missing feature negatively affects perceived autonomy and competence which affects internalization. Self-monitoring enables behavior change because of the

frequent review of records concerning goals, produces accountability and reinforcement (Webb & Wadden, 2017). The more contact, the more reinforcement and increase in motivation (Appel et al., 2011; Booth et al., 2014; Hartmann-Boyce et al., 2014; LeBlanc et al., 2011). Findings also indicate that apps may not allow the user to personalize cues. Although apps may provide general reminders and notifications, personalized cues may help users monitor their behaviors and stay on track for weight loss. Users know themselves and they are better able to target certain behaviors that they should or should not be engaging in to fulfil their goals. The lack of choice on the user's part could affect their perceived autonomy, negatively affecting motivation. Thirdly, findings suggest that almost half of popular apps do not provide reward for goal progress. Rewards could give users a sense of competence and motivate them to engage in weight loss behaviors. Finally, findings indicate that apps do a poor job of helping users to identify barriers to success and assist with overcoming these barriers. This limitation may affect a user's sense of competence. Focusing more on barrier identification and solutions enables effective skill development to effectively manage problems (Foster et al., 2005). These missing features may be hampering internalization affecting long-term engagement in weight loss behaviors and thus effective weight loss.

Calorie counter apps should pursue simulated support strategies to obtain better results. This simulated support may one day mimic human mentoring, coaching, and interventions through the use of artificial intelligence. Designers are wise to consider how to incorporate the "Human in the Loop" to build a simulated support system among existing available resources.

#### Limitations

This study's analysis was limited by the heterogeneous nature of behavioral interventions that may be idiosyncratic to individuals. Effectiveness factors that led to the development of the

Weight Loss Behavior Model were derived from published effectiveness factors associated with behavioral interventions. The effectiveness of behavioral interventions can be affected by varying limitations that were beyond the scope of this study. Consideration for how our environment and culture do not support weight loss but in some cases, nurtures obesity through marketing campaigns, inexpensive convenience foods, and fast food drive throughs. However, obesity is not only caused by environmental factors (Webb & Wadden, 2017). For certain individuals, controlling diet and physical activity is sufficient to produce weight loss. Yet for others, obesity can be affected by factors such as an individual's genes, metabolism, ethnicity, culture, and economic factors (Fitzgibbon et al., 2012; Webb & Wadden, 2017). Additionally, the heterogeneity of behavioral interventions affect the degree of weight loss that can be achieved. The variation in the degree of support (i.e., counseling intensity and duration) has a direct impact on the amount of weight loss that can be achieved (Hartmann-Boyce et al., 2014). Furthermore, behavioral interventions are plagued by high attrition rates and minor, if not any, support for weight maintenance after treatment leading to weight regain (Levine et al., 2015; Webb & Wadden, 2017).

Secondly, weight management and weight loss can be affected by many other factors such as environment, culture, body type, medications, and disease. The Weight Loss Behavior Model, and the functional design requirements derived from the model does not take these factors into account. The functional design requirements defined here may merely apply to individuals in typical situations.

Thirdly, this analysis was conducted by only one evaluator. Having more than one evaluator could serve to test the reliability of the design requirements. Furthermore, apps undergo frequent updates. The apps that were analyzed for this study likely have new features. Running the analysis may yield different results. Additionally, this study only considered the free version of apps.



Purchasing additional app features may have improved the functionality of the apps. The results of this analysis could be different if paid features were also analyzed.

Finally, this analysis solely focuses on calorie counter apps available on the iOS platform and the most popular ones at that. The findings of this analysis, therefore, does not allow for generalizability to all calorie counters apps that are commercially available.

### Research Implications

This study contributed to the literature regarding the effectiveness of calorie counter applications for supporting weight loss. This study produced a design framework consisting of a model and design requirements. The Weight Loss Behavior Model can help with the understanding of how weight loss occurs through a focus on the components that interact to promote weight loss. The functional design requirements can be used for analyzing as well as designing calorie counters that would in theory support effective weight loss in mHealth apps. Furthermore, future research can build on this work for the continued improvement of calorie counters for supporting effective weight loss.

## CHAPTER FIVE: FUTURE RESEARCH

Chapter four reported the findings of the study analysis related to calorie counter weight loss apps. The importance of motivation was emphasized to persist in using apps to achieve desired goals whether used in formal or informal contexts.

Gamification mechanics, such as badges and points, have been increasingly designed into calorie counters to increase their appeal. Gamification, defined as “the use of game design elements in non-game contexts” (Deterding, Dixon, Khaled, & Nacke, 2011, p. 10) is most effective when used for encouragement to make progress, to motivate action, to influence behavior, and to drive knowledge acquisition (Kapp, 2013). Gamification has the potential to increase effectiveness and users’ intrinsic motivation if mechanics are incorporated appropriately into the design of calorie counter apps. This study explored factors related to motivation as used in calorie counter apps but did not analyze the mechanics of how gamification was used. There are fewer studies related to the effectiveness of gamification and the mechanics that can be manipulated by users to promote autonomy and learner control for self-regulated learning.

The functional design requirements could also be used to design a calorie counter app that utilizes self-monitoring data from wearable devices and smart scales to simulate how a user’s weight loss may affect their body. By adopting a modeling and simulation approach, the app will not only improve motivation but also introduce missing support features. By generating a model of the user’s current body composition, the user will be able to observe what happens to their body based on their food intake and physical activity behavior (Milliard, 2016). This feature could facilitate the incorporation of self-monitoring, goal-setting, and support functional design requirements.

Emerging technology such as wearable devices and smart scales, has the potential to ease the burden

of self-monitoring physical activity and weight. Future research can look into how data from these devices can feed simulated avatars in calorie counters.

Future research could also involve utilizing the functional design requirements defined in this study to design and develop a calorie counter app as a prototype to use with human subjects. This prototype app could be used in an experiment to evaluate if the incorporation of the requirements leads to increased motivation and effective weight loss.

Furthermore, the requirements need to be validated by running an evaluation on a greater sample of apps and including more than one evaluator for inter-rater reliability.

Other research questions that can follow up on this study include:

- What factors and mechanics of gamification impact intrinsic motivation?
- How can functional requirements be made to help mobile apps build other skills such as improved visualization using a modeling and simulation approach?
- What is the role of mHealth apps to create habits that lead to a lifestyle change?
- How can app technology integrate with other technologies such as personal assistants that use machine learning and artificial intelligence to promote Human-in-the-Loop capabilities?

In summary, the potential for future research to promote weight loss and wellness using mHealth apps has many possibilities to use the functional requirements created as a contribution resulting from this study. Implications for future research involving wearable technologies and the use of gamified design strategies are discussed.

**APPENDIX: CALO-RE TAXONOMY BEHAVIOR CHANGE  
TECHNIQUES**

<b>Behavior Change Technique associated with intervention effectiveness</b>	<b>Description</b>	<b>Theoretical Foundations</b>	<b>Behavior Change/Outcome</b>	<b>Reference</b>
<b>Provide information on consequences of behavior in general</b>	Provide information about the relationship between the behavior and its possible or likely consequences in general (based on epidemiological data, not an individual's data).	TRA, TPB, SCogT, IMB	Weight loss	Providing general information on consequences of PA behavior is associated with negative moderator effects on weight loss (Dombrowski et al., 2012).
<b>Provide information on consequences of behavior to the individual</b>	Provide information about the benefits and costs of action on inaction to the individual.		Dietary behavior	Providing benefit and costs information based on an individual's positive or negative dietary behavior is associated with dietary behavior change (Lara et al., 2014).
<b>Goal-setting of behavior</b>	Set behavioral goals (e.g., eat more protein next week).	CT	Physical activity and dietary behavior	Setting specific diet and PA behavior goals is associated with dietary and PA behavior change (Samdal et al., 2017).
<b>Goal-setting of outcome</b>	Set outcome goals (e.g., increase muscle mass).	CT	Physical activity behavior, weight loss	Setting dietary outcome goals is associated with positive dietary behavior change (Hankonen et al., 2015; Lara et al., 2014); Setting dietary and PA outcome goals associated with weight loss (Hankonen et al., 2015).
<b>Action planning</b>	Detailed planning of what a person will do (includes when / where).	CT	Physical activity behavior	Being detailed about planning PA is associated with a higher level physical activity behavior change (Williams & French).
<b>Barrier identification/problem solving</b>	Person is prompted to think about possible barriers to performance <i>and</i> identify ways to overcome them.	SCogT	Physical activity and dietary behavior	Identifying barriers to and problem solving strategies for positive dietary intake and increased PA is associated with dietary and PA behavior change (Lara et al., 2014; Samdal et al., 2017).
<b>Set graded tasks</b>	Target behavior is broken down into smaller easily attainable tasks allowing the person to build on small successes in achieving target behavior.	SCogT	Physical activity and dietary behavior	Dividing diet and PA goals in small tasks is associated with positive dietary and PA behavior change (Samdal et al., 2017; Williams & French, 2011)
<b>Prompt rewards contingent on effort or progress towards behavior</b>	The person uses praise or rewards for attempts at achieving behavioral goals (may include self-reward).	OC	Physical activity behavior	Using praise or rewards for attempts at increasing physical activity is associated

<b>Behavior Change Technique associated with intervention effectiveness</b>	<b>Description</b>	<b>Theoretical Foundations</b>	<b>Behavior Change/Outcome</b>	<b>Reference</b>
				with PA behavior change (Olander et al., 2013; Williams & French, 2011).
<b>Prompt self-monitoring of behavior</b>	The person is asked to keep a record to track specified behavior/s (e.g., keeping a diary to track behavior in terms of type, frequency, duration, intensity).	CT	Physical activity and dietary behavior, weight loss	Self-monitoring diet and PA is associated with dietary and PA behavior change (Samdal et al., 2017) and consequently calorie counting is associated with positive effects on weight loss (Dombrowski et al., 2012; Hartmann-Boyce et al., 2014).
<b>Prompt self-monitoring of outcome</b>	The person is asked to keep a record of specific expected measures due to behavior change (e.g., keep a diary to track outcomes such as weight loss, BMI).	CT	Physical activity behavior	Self-monitoring PA outcomes is associated with PA behavior change (Olander et al., 2013).
<b>Provide feedback on performance</b>	Provide the person feedback on their recorded behavior or comment on the person's behavioral performance (e.g., identifying a discrepancy between a set goal and performance).	CT	Physical activity and dietary behavior	Providing feedback on a person's diet or physical activity is associated with dietary and PA behavior change (Lara et al., 2014; Samdal et al., 2017).
<b>Provide instruction on how to perform the behavior</b>	<i>Telling</i> a person <i>how</i> to perform a behavior or preparatory behavior in writing or verbally.	SCogT	Weight loss, kilo calorie intake, physical activity behavior	Dietary instructions are associated with positive moderator effects on weight loss and kilo calorie intake (Dombrowski et al., 2012). Providing instructions on PA behaviors is associated with higher level of physical activity behavior change (Williams & French, 2011).
<b>Model/Demonstrate the behavior</b>	<i>Showing</i> the person how to perform a behavior through physical or visual demonstration remotely or in person.	SCogT	Physical activity and dietary behavior, weight loss	Showing a person how to improve diet and PA is associated with dietary and PA behavior change (Samdal et al., 2017); Showing a person how to eat healthy (e.g., meal prep, cooking video) is associated with weight loss (Hartmann-Boyce et al., 2014).
<b>Teach to use prompts/cues</b>	Teach the person to identify environmental prompts/cues which can be used as <i>reminders</i> to perform	OC	Physical activity behavior	Reminders for physical activity is associated with PA behavior change (Olander et al., 2013).

<b>Behavior Change Technique associated with intervention effectiveness</b>	<b>Description</b>	<b>Theoretical Foundations</b>	<b>Behavior Change/Outcome</b>	<b>Reference</b>
	the behavior, or an alternate behavior in the case of reducing a particular behavior (e.g., smartphone alerts, time of day).			
<b>Prompt practice</b>	The person is prompted to rehearse and repeat the behavior (can include parts of the behavior, e.g., refusal skills in relation to unhealthy snacks) or preparatory behaviors numerous times in an effort to build habits or routines.	OC	Physical activity behavior, weight loss	Prompting rehearsal of PA behaviors associated with PA behavior change (Olander et al., 2013) and positive moderator effects on weight loss (Dombrowski et al., 2012).
<b>Use of follow up prompts</b>	Follow-up with the person for longer period of time (e.g., via phone calls or letters).	OC	Dietary behavior	Follow up with a person with regards to dietary behavior is associated with dietary behavior change (Lara et al., 2014).
<b>Facilitate social comparison</b>	Elicit comparisons by drawing the person's attention to others' performance.	SCompT		
<b>Plan social support/social change</b>	Prompt the person to plan on how to elicit social support from others (e.g., family, friends, partner) to help achieve target behavior/outcomes.	Social support theories	Physical activity and dietary behavior, weight loss	Eliciting social support for improving diet and PA behaviors is associated with dietary, PA behavior change, and weight loss (Greaves et al., 2011; Lara et al., 2014; Samdal et al., 2017).
<b>Prompt review of behavioral goals</b>	Encourage person to review extent to which set goals were achieved and revise/readjust goals or means as necessary.		Physical activity and dietary behavior, weight loss	Reviewing diet and PA goals are associated with dietary, PA behavior change, and weight loss (Hankonen et al., 2015; Samdal et al., 2017).
<b>Relapse prevention/Coping planning</b>	The person is prompted to identify situations in which the changed behavior may not be maintained and to devise strategies to avoid or manage those situations.	Relapse Prevention Theory	Physical activity and dietary behavior, weight loss	Planning for dietary and PA relapse is associated with dietary and PA behavior change, and weight loss (Dombrowski et al., 2012; Hankonen et al., 2015; Lara et al., 2014; Michie, Abraham, Whittington, McAteer, & Gupta, 2009; Williams & French).
<b>Motivational interviewing</b>	Clinical technique involving prompting the person to engage in		Dietary behavior	Motivational interviewing with regard to diet is associated with dietary behavior change (Lara et al., 2014).

Behavior Change Technique associated with intervention effectiveness	Description	Theoretical Foundations	Behavior Change/Outcome	Reference
	change talk to minimize resistance and resolve ambivalence to change.			



## LIST OF REFERENCES

- Allen, J. K., Stephens, J., Dennison Himmelfarb, C. R., Stewart, K. J., & Hauck, S. (2013). Randomized controlled pilot study testing use of smartphone technology for obesity treatment. *Journal of obesity*, 2013(ID 151597).
- Anderson, D. A., Shapiro, J. R., & Lundgren, J. D. (2001). The behavioral treatment of obesity. *Behavior Analyst Today*, 2(2), 133-140.
- Anderson, J. W., & Konz, E. C. (2001, November 1). Obesity and Disease Management: Effects of Weight Loss on Comorbid Conditions. *Obesity Research*, 9(S11), 326S-334S.
- App Annie. (2019, August 14-16). *iOS Top App Charts*. Retrieved from App Annie: [https://www.appannie.com/apps/ios/top-chart/?country=US&category=6013&device=iphone&date=2019-10-23&feed=Free&rank\\_sorting\\_type=rank&page\\_number=0&page\\_size=100&table\\_selections=&metrics=&order\\_type=desc&order\\_by=free\\_rank](https://www.appannie.com/apps/ios/top-chart/?country=US&category=6013&device=iphone&date=2019-10-23&feed=Free&rank_sorting_type=rank&page_number=0&page_size=100&table_selections=&metrics=&order_type=desc&order_by=free_rank)
- Appel, L. J., Clark, J. M., Yeh, H. C., Wang, N. Y., Coughlin, J. W., Daumit, G., . . . Brancati, F. L. (2011). Comparative effectiveness of weight-loss interventions in clinical practice. *New England Journal of Medicine*, 365(21), 1959-1968.
- Apple Inc. (n.d.). *App Store*. Retrieved from <https://www.apple.com/ios/app-store/>
- Azar, K. M., Lesser, L. I., Laing, B. Y., Stephens, J., Aurora, M. S., Burke, L. E., & Palaniappan, L. P. (2013). Mobile applications for weight management: theory-based content analysis. *American journal of preventive medicine*, 45(5), 583-589.
- Baker, R. C., & Kirschenbaum, D. S. (1993). Self-monitoring may be necessary for successful weight control. *Behavior Therapy*, 24(3), 377-394.

- Bardus, M., van Beurden, S. B., Smith, J. R., & Abraham, C. (2016). A review and content analysis of engagement, functionality, aesthetics, information quality, and change techniques in the most popular commercial apps for weight management. *International Journal of Behavioral Nutrition and Physical Activity*, 13(1).
- Bentley, J. (2017). *U.S. Trends in Food Availability and a Dietary Ass.*; U.S. Department of Agriculture, Economic Research Service.
- Blackburn, G. (1995). Effect of degree of weight loss on health benefits. . *Obesity*.(3), S2.
- Booth, H. P., Prevost, T. A., Wright, A. J., & Gulliford, M. C. (2014). Effectiveness of behavioural weight loss interventions delivered in a primary care setting: a systematic review and meta-analysis. *Family practice*, 31(6), 643-653.
- Brindal, E., Hendrie , G., Freyne , J., Coombe, M., Berkovsky, S., & Noakes, M. (2013). Design and pilot results of a mobile phone weight-loss application for women starting a meal replacement programme. *Journal of telemedicine and telecare*, 19(3), 166-174.
- Brown, J. D., Buscemi, J., Milsom, V., Malcolm, R., & O'Neil, P. M. (2016). Effects on cardiovascular risk factors of weight losses limited to 5–10 %. *Translational Behavioral Medicine*, 6(3), 339-346.
- Burke, L. E., Wang, J., & Sevick, M. A. (2011). Self-monitoring in weight loss: a systematic review of the literature. *Journal of the American Dietetic Association*, 111(1), 92-102.
- Butryn, M. L., Webb, V., & Wadden, T. A. (2011, 12 1). Behavioral Treatment of Obesity. *Psychiatric Clinics*, 34(4), 841-859.
- CalorieKing. (2013). Retrieved from <https://apps.apple.com/us/app/controlmyweight/id578546778>

- Carter, M. C., Burley, V. J., Nykjaer, C., & Cade, J. E. (2013). Adherence to a smartphone application for weight loss compared to website and paper diary: pilot randomized controlled trial. *Journal of medical Internet research*, 15(4).
- Centers for Disease Control and Prevention. (2016, June 16). Retrieved from Centers for Disease Control and Prevention: <https://www.cdc.gov/obesity/adult/defining.html>
- Chen, J., Cade, J. E., & Allman-Farinelli, M. (2015). The most popular smartphone apps for weight loss: a quality assessment. *JMIR mHealth and uHealth*, 3(4).
- Clarke, T. C., Norris, T., & Schiller, J. S. (2017). *Early Release of Selected Estimates Based on Data From the 2016 National Health Interview Survey*. NATIONAL CENTER FOR HEALTH STATISTICS.
- Cronometer Software Inc. (2011). Retrieved from <https://apps.apple.com/us/app/cronometer-nutrition-tracker/id1145935738>
- Davis, S. F., Ellsworth, M. A., Payne, H. E., Hall, S. M., West, J. H., & Nordhagen, A. L. (2016). Health behavior theory in popular calorie counting apps: a content analysis. *MIR mHealth and uHealth*, 4(1).
- Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum.
- Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological inquiry*, 11(4), 227-268.
- Deci, E. L., & Ryan, R. M. (2015). Self-determination theory. In J. D. Wright, *International Encyclopedia of the Social & Behavioral Sciences* (Vol. 21). Amsterdam: Elsevier.

- Deterding, S., Dixon, D., Khaled, R., & Nacke, L. E. (2011). From game design elements to gamefulness: defining "gamification". *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments.*, (pp. 9-15).
- Diabetes Prevention Program Research Group. (2002, February 7). Reduction in the Incidence of Type 2 Diabetes with Lifestyle Intervention or Metformin. *New England Journal of Medicine*, *346*(6), 393-403.
- Direito, A., Dale, L. P., Shields, E., Dobson, R., Whittaker, R., & Maddison, R. (2014). Do physical activity and dietary smartphone applications incorporate evidence-based behaviour change techniques? *BMC public health*, *14*(1), 646.
- Dombrowski, S. U., Snichotta, F. F., Avenell, A., Johnston, M., MacLennan, G., & Araújo-Soares, V. (2012). Identifying active ingredients in complex behavioural interventions for obese adults with obesity-related co-morbidities or additional risk factors for co-morbidities: a systematic review. *Health Psychology Review*, *6*(1), 7-32. doi:<https://doi.org/10.1080/17437199.2010.513298>
- FatSecret. (n.d.). Retrieved from <https://apps.apple.com/us/app/calorie-counter-by-fatsecret/id347184248>
- Fitbit Inc. (2011). Retrieved from <https://apps.apple.com/us/app/fitbit/id462638897>
- FitNow Inc. (2008). Retrieved from <https://apps.apple.com/us/app/lose-it-calorie-counter/id297368629>
- Fitzgibbon, M. L., Tussing-Humphreys, L. M., Porter, J. S., Martin, I. K., Odoms-Young, A., & Sharp, L. K. (2012). Weight loss and African–American women: a systematic review of the behavioural weight loss intervention literature. *Obesity Reviews*, *13*(3), 193-213.

- Flores Mateo, G., Montaña-Carreras, X., Granado-Font, E., & Ferré-Grau, C. (2015). Mobile phone apps to promote weight loss and increase physical activity: a systematic review and meta-analysis. *Journal of medical Internet research*, 11.
- Fooducate Ltd. (2010). Retrieved from <https://apps.apple.com/us/app/fooducate-diet-nutrition/id398436747>
- Foodvisor. (n.d.). Retrieved from <https://apps.apple.com/us/app/foodvisor-calorie-counter/id1064020872>
- Foster, G. D., Makris, A. P., & Bailer, B. A. (2005, July 1). Behavioral treatment of obesity. *The American Journal of Clinical Nutrition*, 82(1), 230S-235S.
- Franz, M. J., VanWormer, J. J., Crain, A. L., Boucher, J. L., Histon, T., Caplan, W., . . . Pronk, N. P. (2007, October 1). Weight-Loss Outcomes: A Systematic Review and Meta-Analysis of Weight-Loss Clinical Trials with a Minimum 1-Year Follow-Up. *Journal of the Academy of Nutrition and Dietetics*, 107(10), 1755-1767.
- Fryar, C. D., Carroll, M. D., & Ogden, C. L. (2016, July). *Prevalence of overweight, obesity, and extreme obesity among adults aged 20 and over: United States, 1960–1962 through 2011–2014*. Retrieved from [https://www.cdc.gov/nchs/data/hestat/obesity\\_adult\\_13\\_14/obesity\\_adult\\_13\\_14.htm](https://www.cdc.gov/nchs/data/hestat/obesity_adult_13_14/obesity_adult_13_14.htm)
- Gee, P. M., Greenwood, D. A., Paterniti, D. A., Ward, D., & Miller, L. (2015). The eHealth enhanced chronic care model: a theory derivation approach. *Journal of medical Internet research*, 17(4).
- Gillison, F. B., Rouse, P., Standage, M., Sebire, S. J., & Ryan, R. M. (2019). A meta-analysis of techniques to promote motivation for health behaviour change from a self-determination theory perspective. *Health psychology review*, 13(1), 110-130.

- Goldstein, D. J. (1992). Beneficial health effects of modest weight loss. *International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity*, 16(6), 397-415.
- Google. (n.d.). Retrieved from Google Play: [https://play.google.com/store/apps?hl=en\\_US](https://play.google.com/store/apps?hl=en_US)
- Greaves, C. J., Sheppard, K. E., Abraham, C., Hardeman, W., Roden, M., Evans, P. H., & Schwarz, P. (2011). Systematic review of reviews of intervention components associated with increased effectiveness in dietary and physical activity interventions. *BMC public health*, 11, 119.
- Guh, D. P., Zhang, W., Bansback, N., Amarsi, Z., Birmingham, C. L., & Anis, A. H. (2009, March 25). The incidence of co-morbidities related to obesity and overweight: A systematic review and meta-analysis. *BMC Public Health*, 9(88).
- Guth, E. (2018, January 16). Counting Calories as an Approach to Achieve Weight Control. *JAMA*, 319(3), 225-226.
- Hankonen, N., Sutton, S., Prevost, A. T., Simmons, R. K., Griffin, S. J., Kinmonnth, A. L., & Hardeman, W. (2014). Which behavior change techniques are associated with changes in physical activity, diet and body mass index in people with recently diagnosed diabetes? *Annals of Behavioral Medicine*, 49(1), 7-17.
- Hartmann-Boyce, J., Johns, D. J., Jebb, S. A., & Aveyard, P. (2014, July 1). Effect of behavioural techniques and delivery mode on effectiveness of weight management: systematic review, meta-analysis and meta-regression. *Obesity Reviews*, 15(7), 598-609.
- Hassan, Y., Head, V., Jacob, D., Bachmann, M. O., Diu, S., & Ford, J. (2016). Lifestyle interventions for weight loss in adults with severe obesity: a systematic review. *Clinical obesity*, 6(6), 395-403.

HIMMS. (2012, January 5). *Defenitions of mHealth*. Retrieved from HIMMS.org:

<https://www.himss.org/definitions-mhealth>

InspiredApps. (n.d.). Retrieved from <https://apps.apple.com/us/app/my-diet-coach-weight-loss/id552341639>

Jacobs, S., Radnitz, C., & Hildebrandt, T. (2017). Adherence as a predictor of weight loss in a commonly used smartphone application. *Obesity research & clinical practice*, 11(2), 206-214.

Jake-Schoffman, D. E., Silfee, V. J., Waring, M. E., Boudreaux, E. D., Sadasivam, R. S., Mullen, S. P., . . . Pagoto, S. L. (2017). Methods for evaluating the content, usability, and efficacy of commercial mobile health apps. *JMIR mHealth and uHealth*, 5(12).

Jensen, M. D., Ryan, D. H., Apovian, C. M., Ard, J. D., Comuzzie, A. G., Donato, K. A., . . . Wol. (2014, June 24). 2013 AHA/ACC/TOS Guideline for the Management of Overweight and Obesity in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society. *Circulation*, 129(25 suppl 2), S102-S138.

Johns, D. J., Hartmann-Boyce, J., Jebb, S. A., & Aveyard, P. (2014). Diet or exercise interventions vs combined behavioral weight management programs: a systematic review and meta-analysis of direct comparisons. *Journal of the Academy of Nutrition and Dietetics*, 114(10), 1557-1568.

Kapp, K. M. (2013). *The gamification of learning and instruction fieldbook: Ideas into practice*. . San Francisco: John Wiley & Sons.

Kent, S., Fusco, F., Gray, A., Jebb, S. A., Cairns, B. J., & Mihaylova, B. (2017, August 1). Body mass index and healthcare costs: a systematic literature review of individual participant data studies. *Obesity Reviews*, 18(9), 869-879.

- Krebs, P., & Duncan, D. T. (2015). Health App Use Among US Mobile Phone Owners: A National Survey. *JMIR mHealth and uHealth*, 3(4).
- Krippendorff, K. (2018). *Content analysis: An introduction to its methodology*. Thousand Oaks, California: Sage Publications.
- Kritchevsky, S. B., Beavers, K. M., Miller, M., Shea, M. K., Houston, D. K., Kitzman, D., & Nicklas, B. J. (2015, March 20). Intentional Weight Loss and All-Cause Mortality: A Meta-Analysis of Randomized Clinical Trials. *PLOS ONE*, 10(3).
- Laing, B. Y. (2014). Effectiveness of a smartphone application for weight loss compared with usual care in overweight primary care patients: a randomized, controlled trial. *Annals of internal medicine*, 161(10\_Supplement), S5-S12.
- Lara, J., Evans, E. H., O'Brien, N., Moynihan, P. J., Meyer, T., Adamson, A. J., . . . Mathers, J. C. (2014). Association of behaviour change techniques with effectiveness of dietary interventions among adults of retirement age: a systematic review and meta-analysis of randomised controlled trials. *BMC medicine*, 12(1), 177-189.
- Leaf Group Ltd. (n.d.). Retrieved from <https://apps.apple.com/us/app/myplate-calorie-counter/id502317923>
- LeBlanc, E. S., O'Connor, E., Whitlock, E. P., Patnode, C. D., & Kapka, T. (2011, October 4). Effectiveness of Primary Care–Relevant Treatments for Obesity in Adults: A Systematic Evidence Review for the U.S. Preventive Services Task Force. *Annals of Internal Medicine*, 155(7), 434-447.
- LeBlanc, E. S., O'connor, E., Whitlock, E. P., Patnode, C. D., & Kapka, T. (2011). Effectiveness of primary care–relevant treatments for obesity in adults: a systematic evidence review for the US Preventive Services Task Force. *Annals of internal medicine*, 155(7), 434-447.



- Levine, D. M., Savarimuthu, S., Squires, A., Nicholson, J., & Jay, M. (2015, January 1). Technology-Assisted Weight Loss Interventions in Primary Care: A Systematic Review. *Journal of General Internal Medicine*, *30*(1), 107-117.
- Levine, D. M., Savarimuthu, S., Squires, A., Nicholson, J., & Jay, M. (2015). Technology-assisted weight loss interventions in primary care: a systematic review. *Journal of general internal medicine*, *30*(1), 107-117.
- Lister, C., West, J. H., Cannon, B., Sax, T., & Brodegard, D. (2014). Just a fad? Gamification in health and fitness apps. *JMIR serious games*, *2*(2).
- Mata, J., Silva, M. N., Vieira, P. N., Carraça, E. V., Andrade, A. M., Coutinho, S. R., . . . Teixeira, P. (2009). Motivational “spill-over” during weight control: Increased self-determination and exercise intrinsic motivation predict eating self-regulation. *Health Psychology*, *28*(6), 709.
- Mattila, E., Orsama, A. L., Ahtinen, A., Hopsu, L., Leino, T., & Korhonen, I. (2013). Personal health technologies in employee health promotion: usage activity, usefulness, and health-related outcomes in a 1-year randomized controlled trial. *MIR mHealth and uHealth*, *1*(2).
- Michie, S., Ashford, S., Sniehotta, F. F., Dombrowski, S. U., Bishop, A., & French, D. P. (2011). A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: the CALO-RE taxonomy. *Psychology & health*, *26*(1), 479-1498.
- Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., . . . Wood, C. (2013, March 20). The Behavior Change Technique Taxonomy (v1) of 93 Hierarchically Clustered Techniques: Building an International Consensus for the Reporting of Behavior Change Interventions. *The Society of Behavioral Medicine*(46), 81-95.

- Milliard, S. (2016, July 8). *Diet and Physical Activity Tracking Apps are in Need of an Innovative Feature for Increased Adherence*. Retrieved November 2019, from Technologically Fit Blog:  
<https://technologicallyfitblog.wordpress.com/2016/07/08/first-blog-post/#more-4>
- Mokdad, A. H., Ford, E. S., Bowman, B. A., Dietz, W. H., Vinicor, F., Bales, V. s., & Marks, J. S. (2003). Prevalence of Obesity, Diabetes, and Obesity-Related Health Risk Factors, 2001. *JAMA*, 289(1).
- Must, A. (1999). The Disease Burden Associated With Overweight and Obesity. *JAMA*, 282(16).
- MyNetDiary Inc.* (n.d.). Retrieved from <https://apps.apple.com/us/app/calorie-counter-mynetdiary/id287529757>
- Nan, L., Azar, K. M., Rosas, L. G., Wulfovich, S., Xiao, L., & Ma, J. (2017). Behavioral lifestyle interventions for moderate and severe obesity: a systematic review. *Preventive medicine*, 100, 180-193.
- National Heart, Lung, and Blood Institute (NHLBI). (n.d.). *Overweight and Obesity*. Retrieved from National Heart, Lung, and Blood Institute (NHLBI): <https://www.nhlbi.nih.gov/health-topics/overweight-and-obesity>
- Ng, J. Y., Ntoumanis, N., Thøgersen-Ntoumani, C., Deci, E., Ryan, R. M., Duda, J. L., & Williams, G. C. (2012). Self-determination theory applied to health contexts: A meta-analysis. *Perspectives on Psychological Science*, 7(4), 325-340.
- Noom Inc. (2010). Retrieved from <https://apps.apple.com/us/app/noom/id634598719>
- NutraTech Ltd. (n.d.). Retrieved from <https://apps.apple.com/gb/app/calorie-counter/id444924121>
- Olson, K., Bond, D., & Wing, R. R. (2017, March). Behavioral approaches to the treatment of obesity. *Rhode Island Medical Journal*, 100(2), 21-24.

- Payne, H. E., Lister, C., West, J. H., & Bernhardt, J. M. (2015, February 26). Behavioral Functionality of Mobile Apps in Health Interventions: A Systematic Review of the Literature. *JMIR mHealth and uHealth*, 3(1).
- Pew Research Center. (2017, January 12). *Mobile Fact Sheet*. Retrieved from <http://www.pewinternet.org/fact-sheet/mobile/>
- Prestwich, A., Webb, T. L., & Conner, M. (2015). Using theory to develop and test interventions to promote changes in health behaviour: evidence, issues, and recommendations. *Current Opinion in Psychology*, 5, 1-5.
- Raaijmakers, L. C., Pouwels, S., Berghuis, K. A., & Nienhuijs, S. W. (2015, December 1). Technology-based interventions in the treatment of overweight and obesity: A systematic review. *Appetite*, 95, 138-151.
- Reed, J. R., Yates, B. C., Houfek, J., Briner, W., Schmid, K., & Pullen, C. H. (2016). Motivational factors predict weight loss in rural adults. *Public Health Nursing*, 33(3), 232-241.
- Rivera, J., McPherson, A., Hamilton, J., Birken, C., Coons, M., Iyer, S., . . . Stinson, J. (2016). Mobile apps for weight management: a scoping review. *JMIR mHealth and uHealth*, 4(3).
- Rosenbaum, D. L., Clark, M. G., Convertino, A. D., Call, C. C., Forman, E. M., & Butryn, M. L. (2018). Examination of Nutrition Literacy and Quality of Self-monitoring in Behavioral Weight Loss. *Annals of Behavioral Medicine*.
- Ross, K. M., & Wing, R. R. (2016). Impact of newer self-monitoring technology and brief phone-based intervention on weight loss: A randomized pilot study. *Obesity*, 24(8), 1653-1659.
- Ryan, R. M., & Deci, E. L. (2000a). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary educational psychology*, 25(1), 54-67.

- Ryan, R. M., & Deci, E. L. (2000b). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist*, *55*(1), 68- 78.
- Ryan, R. M., Patrick, H., Deci, E. L., & Williams, G. C. (2008). Facilitating health behaviour change and its maintenance: Interventions based on self-determination theory. *European Health Psychologist*, *10*(1), 2-5.
- Sama, P. R., Eapen, Z. J., Weinfurt, K. P., Shah, B. R., & Schulman, K. A. (2014). An evaluation of mobile health application tools. *JMIR mHealth and uHealth*, *2*(2).
- Samdal, G. B., Eide, G. E., Barth, T., Williams, G., & Meland, E. (2017). Effective behaviour change techniques for physical activity and healthy eating in overweight and obese adults; systematic review and meta-regression analyses. . *e adults: systematic review and meta-regression analyses. International Journal of Behavioral Nutrition and Physical Activity*, *14*:42.
- Semper , H. M., Povey, R., & Clark-Carter , D. (2016). A systematic review of the effectiveness of smartphone applications that encourage dietary self-regulatory strategies for weight loss in overweight and obese adults. *Obesity reviews*, *17*(9), 895-906.
- Silva, M. N., Markland, D., Carraça, E. V., Vieira, P. N., Coutinho, S. R., Minderico, C. S., . . . Teixeira, P. (2011). Exercise autonomous motivation predicts 3-yr weight loss in women. *Medicine & Science in Sports & Exercise*, *43*(4), 728-737.
- Silva, M. N., Markland, D., Minderico, C., Vieira, P. N., Castro, M. M., Coutinho, S. R., . . . Teixeira, P. J. (2008). A randomized controlled trial to evaluate self-determination theory for exercise adherence and weight control: rationale and intervention description. *BMC public health*, *8*(1), 234.

- Stephens, J. D., Yager, A. M., & Allen, J. (2017). Smartphone Technology and Text Messaging for Weight Loss in Young Adults: A Randomized Controlled Trial. *The Journal of cardiovascular nursing*, 32(1), 39-46.
- Sttir Inc. (n.d.). Retrieved from <https://apps.apple.com/us/app/weight-loss-simple-tracker-app/id1226502637>
- Teixeira, P. J., Silva, M. N., Mata, J., Palmeira, A. L., & Markland, D. (2012). Motivation, self-determination, and long-term weight control. *International Journal of Behavioral Nutrition and Physical Activity*, 9(1), 22.
- Thomas, J. G. (2013). Health-e-call, a smartphone-assisted behavioral obesity treatment: pilot study. *JMIR mHealth and uHealth*(1), 1.
- Thomas, J. G., & Bond, D. S. (2018, June 7). Review of Innovations in Digital Health Technology to Promote Weight Control. *Current Diabetes Reports*, 14(485).
- Thompson-Felty, C., & Johnston, C. S. (2017). Adherence to diet applications using a smartphone was associated with weight loss in healthy overweight adults irrespective of the application. *ournal of diabetes science and technology*, 11(1), 184-185.
- Trief, P. M., Cibula, D., Delahanty, L. M., & Weinstock, R. S. (2017). Self-determination theory and weight loss in a Diabetes Prevention Program translation trial. *Journal of behavioral medicine*, 40(3), 483-493.
- Tsai, A. G., Remmert, J. E., Butryn, M. L., & Wadden, T. A. (2018, January). Treatment of Obesity in Primary Care. *Medical Clinics of North America*, 102(1), 35-47.
- Tufano, J. T., & Karras, B. T. (2005, December 20). Mobile eHealth Interventions for Obesity: A Timely Opportunity to Leverage Convergence Trends. 7(5).

- Turner-McGrievy, G. M., Beets, M. W., Moore, J. B., Kaczynski, A. T., Barr-Anderson, D. J., & Tate, D. F. (2013). Comparison of traditional versus mobile app self-monitoring of physical activity and dietary intake among overweight adults participating in an mHealth weight loss program. *Journal of the American Medical Informatics Association*, 20(3), 513-518.
- U.S. Department of Health and Human Services. (2015, December). *2015 - 2020 Dietary Guidelines for Americans*. Retrieved from health.gov:  
<https://health.gov/dietaryguidelines/2015/guidelines/>
- Under Armour Inc. (2009). Retrieved from  
<https://apps.apple.com/us/app/myfitnesspal/id341232718>
- Wadden, T. A., & Foster, G. D. (2000, March 1). Behavioral Treatment of Obesity. *Medical Clinics*, 84(2), 441-461.
- Wadden, T. A., Butryn, M. L., Hong, P. S., & Tsai, A. G. (2014, November 5). Behavioral Treatment of Obesity in Patients Encountered in Primary Care Settings: A Systematic Review. *JAMA*, 312(17), 1779-1791.
- Wadden, T. A., Webb, V. L., Moran, C. H., & Bailer, B. A. (2012, March 6). Lifestyle Modification for Obesity: New Developments in Diet, Physical Activity, and Behavior Therapy. *Circulation*, 125(9), 1157-1170.
- Wang, J., Sereika, S. M., Chasens, E. R., Ewing, L. J., Matthews, J. T., & Burke, L. E. (2012). Effect of adherence to self-monitoring of diet and physical activity on weight loss in a technology-supported behavioral intervention. *Patient preference and adherence*, 6, 221.
- Webb, V. L., & Wadden, T. A. (2017). Intensive lifestyle intervention for obesity: principles, practices, and results. *Gastroenterology*, 152(7), 1752-1764.

- Webber, K. H., Tate, D. F., Ward, D. S., & Bowling, J. M. (2010). Webber, K. H., Tate, D. F., Ward, D. S., & Bowling, J. M. (2010). Motivation and its relationship to adherence to self-monitoring and weight loss in a 16-week Internet behavioral weight loss intervention. *Journal of nutrition education and behavior*, *42*(3), 161-167.
- West, J. H., Hall, P. C., Hanson, C. L., Barnes, M. D., Giraud-Carrier, C., & Barret, J. (2012). There's an app for that: content analysis of paid health and fitness apps. *Journal of medical Internet research*, *14*(3).
- Wharton, C. M., Johnston, C. S., Cunningham, B. K., & Sterner, D. (2014). Dietary self-monitoring, but not dietary quality, improves with use of smartphone app technology in an 8-week weight loss trial. *Journal of nutrition education and behavior*, *46*(5), 440-444.
- Williams, E. P., Mesidor, M., Winters, K., Dubbert, P. M., & Wyatt, S. B. (2015). Overweight and Obesity: Prevalence, Consequences, and Causes of a Growing Public Health Problem. *Current Obesity Reports*, *4*(3), 363-370.
- Williams, G. C., Cox, E., & Ryan, R. M. (1998). Building health-care partnerships by supporting autonomy: Promoting maintained behavior change and positive health outcomes. In A. L. Suchman, P. Hinton-Walker, & R. Botelho (Eds.), *Partnerships in healthcare: Transforming relational process*. (pp. 67-88). Rochester, NY: University of Rochester Press.
- Williams, G. C., Grow, V. M., Freedman, Z. R., Ryan, R. M., & Deci, E. L. (1996). Motivational predictors of weight loss and weight-loss maintenance. *Journal of personality and social psychology*, *70*(1), 115-126.
- Williamson, D. A., Bray, G. A., & Ryan, D. H. (2015, December 1). Is 5% weight loss a satisfactory criterion to define clinically significant weight loss? *Obesity*, *23*(12), 2319-2320.

- Wing, R. R., Lang, W., Wadden, T. A., Safford, M., Knowler, W. C., Bertoni, A. G., . . . The Look AHEAD Research Group. (2011, July 1). Benefits of Modest Weight Loss in Improving Cardiovascular Risk Factors in Overweight and Obese Individuals With Type 2 Diabetes. *Diabetes Care*, *34*(7), 1481-1486.
- World Health Organization (WHO). (2011). *mHealth. New horizons for health through mobile technologies*.
- World Health Organization (WHO). (2017, May). *10 Facts on obesity*. Retrieved from <http://www.who.int/features/factfiles/obesity/en/>
- Wright, S. M., & Aronne, L. J. (2012). Causes of obesity. *Abdominal Imaging*, *37*(5), 730-732.
- Wyatt, S. B., Winters, K. P., & Dubbert, P. M. (2006). Overweight and obesity: prevalence, consequences, and causes of a growing public health problem. *The American journal of the medical sciences*, *331*(4), 166-174.
- YAZIO GmbH. (n.d.). Retrieved from <https://apps.apple.com/us/app/yazio-diet-food-tracker/id946099227>