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Content Analysis of Diet-Related Mobile Apps: A Self-Regulation Perspective

Nagwan R. Zahry [a], Ying Cheng [b], and Wei Peng [c]

[a]Department of Advertising and Public Relations, Michigan State University; [b]Department of Communication, Michigan State University; [c]Department of Media and Information, Michigan State University

ABSTRACT

Diet-related mobile apps hold promise in helping individuals self-regulate their eating behaviors. Nevertheless, little is known about the extent to which diet-related mobile apps incorporate the established behavior change theories and evidence-based practices that promote dietary self-regulation. Guided by the self-regulation aspect of Bandura's social cognitive theory and the Dietary Guidelines for Americans 2010 of the U.S. Department of Agriculture, this study conducts a content analysis of diet-related mobile apps for iPhone (N = 400). In terms of the adherence to the self-regulation aspect of the social cognitive theory, results show that although 72.5% of the apps incorporate at least one theoretical construct, few apps tap all three processes of self-regulation (i.e., self-observation/monitoring, judgment process, and self-reaction). Additionally, outcome expectation is manifested in a majority of the diet-related apps. In terms of the Dietary Guidelines for Americans 2010, while the diet-related apps equally emphasize setting goals for calorie intake or nutrient consumption, more apps feature nutrient tracking than calorie tracking. Implications and limitations are discussed.

Obesity persists as a serious health problem in the United States. From 2003 to 2012, more than one-third of adults in the United States were obese (Ogden, Carroll, Kit, & Flegal, 2014). Moreover, obesity increases the risk of chronic diseases, such as heart attack, stroke, type 2 diabetes, and cancer (National Institutes of Health [NIH], 1998). Since obesity results from energy imbalance (i.e., calorie intake exceeds consumption), one intervention strategy to obesity involves promoting healthy dietary behaviors (NIH, 1998). According to the Dietary Guidelines for Americans 2010 (U.S. Department of Agriculture [USDA], 2011), healthy eating involves maintaining calorie balance and consuming nutrient-dense foods.

Self-regulation significantly predicts healthy dietary behaviors (Anderson, Winett, & Wojcik, 2007). The social cognitive theory proposes that self-regulation consists of three subprocesses: self-monitoring, judgment, and self-reaction (Bandura, 1991). Through recording food and beverage intake, self-monitoring can enhance people's self-awareness of dietary behaviors (Heatherton, Polivy, Herman, & Baumeister, 1993). Setting realistic dietary goals enhances people's self-efficacy, which ultimately leads to healthy eating (Schnoll & Zimmerman, 2001). Through assessing performance toward goal and rewarding goal attainment, self-reaction can improve people's motivations and sustain desirable outcomes (Cullen, Baranowski, & Smith, 2001).

Information technologies such as mobile phones, especially smartphone apps, are becoming a promising platform in helping people self-regulate their eating behaviors by making information "portable, personalized and participatory" (Fox, 2010). To date, researchers have tested the effectiveness of mobile applications that incorporate self-regulation aspects in promoting dietary behaviors in experimental settings (Acharya, Elci, Sereika, Styn, & Burke, 2011; Welch et al., 2013).

A number of studies have content analyzed features of publicly available apps in the Apple App Store and Google Play store (Azar et al., 2013; Breton, Fuemmeler, & Abroms, 2011). Some of these studies attempted to provide a comprehensive picture of health and fitness apps (Cowan et al., 2013; West et al., 2012). Other studies focused on particular diseases or health conditions, such as smoking (Abroms, Padmanabhan, Thaweethai, & Phillips, 2011), diabetes management (Breland, Yeh, & Yu, 2013), and weight loss (Breton et al., 2011). To our best knowledge, despite the attention of some studies to weight loss mobile apps that encouraged both physical activity and a healthy diet, none of the available studies focused primarily on diet-related apps. Additionally, few content analysis studies utilized a theoretical framework or evidence-based practice in the analysis (e.g., Azar el al., 2013; Pagoto, Schneider, Jojic, DeBiasse, & Mann, 2013; West et al., 2013). Among the content analysis studies that utilized a theoretical framework, only a small sample of apps was examined, of which none focused on diet-related apps. Further, little is known about the quality of publicly available apps in terms of self-regulating dietary behaviors.

This study, therefore, seeks to fill this gap by assessing the features of diet-related mobile apps using a theoretical framework, namely, social cognitive theory (Bandura, 1991), and evidence-based practices, namely, Dietary Guidelines for

CONTACT Wei Peng, PhD, Assistant Professor penwei@msu.edu Department of Media and Information, College of Communication Arts and Sciences, Michigan State University, 430 Comm Arts Building, East Lansing, MI 48824.

The first and second authors contributed equally to the project.

Americans 2010 (USDA, 2011). The theoretical framework of social cognitive theory was used to guide the content analysis, since it is one of the most effective theoretical lenses to design interventions for diet and weight management (Anderson et al., 2007; Burke, Wang, & Sevick, 2011). The theory serves as a systematic platform to develop the coding scheme that includes the main behavioral strategies of self-regulation incorporated in diet mobile apps' features. Although this study does not aim to directly test the effectiveness of diet-related mobile apps, this theory-driven content analysis may serve as an indirect evaluation of diet mobile apps available to the public based on their adherence to well-established theoretical framework. Further, the use of theory-based content analysis can provide a preliminary assessment of the apps, which, in turn, can narrow down the number of apps that researchers can test in randomized control trials or clinical settings (Riley et al., 2011). The 2010 USDA dietary guidelines for Americans were chosen due to their evidence-based nature and utilization in successful interventions for diet and weight management using emerging technologies (Cullen, Thompson, Boushey, Konzelmann, & Chen, 2013; Kalarchian, Levine, & Marcus, 2013).

Literature review

Mobile apps

Fifty-six percent of American adults have smartphones (Smith, 2013). The number of health and fitness apps from Apple's App Store skyrocketed from 2,993 in 2010 to 13,619 in 2012 (Butler, 2012). The Google Play store has 36,260 health and fitness apps (AppBrain Stats, 2014). According to the Pew Internet and American Life Project, 52% of smartphone owners use their phones to seek health information (Fox & Duggan, 2012). Their ease of use, portability, immediacy, accessibility, interactivity, and wireless data networks qualify smartphones to play a significant role in promoting health behaviors (Patrick, Griswold, Raab, & Intille, 2008).

Empirical studies demonstrate that smartphone applications are effective in promoting diet-related behavior change. For instance, Toscos, Feber, An, and Gandhi (2006) showed that mobile apps encouraged adolescent girls to monitor their food intake and discuss healthy behavior with their peers. Similarly, Turner-McGrievy et al. (2013) concluded that users who monitored their food intake using mobile applications consumed less calories compared to paper journal users. Of note, some of the apps used in these studies were specifically developed for research purposes and were designed using theoretical underpinnings. However, it is unclear whether the publicly available apps in the Apple App Store and the Google Play app store can be effective in self-regulating eating behavior. One initial step to address this issue is to examine whether these apps are designed with theoretical underpinnings that can induce positive eating behavior.

Social cognitive theory and self-regulation processes

Social cognitive theory has been extensively applied in promoting healthy practices, such as dietary behaviors (Anderson, Winett, Wojcik, Winett, & Bowden, 2001; Baranowski et al., 1993). According to social cognitive theory, self-regulation involves three main processes: self-observation (i.e., self-monitoring), judgment process, and self-reaction. Through the process of self-monitoring, individuals diagnose their behavioral patterns and the physical and social factors that influence their behaviors. In the context of monitoring dietary behaviors using mobile apps, the quality of self-monitoring depends on the extent to which an app records the quality, quantity, and time of food consumption accurately, the regularity of self-monitoring, and the intervals between dietary behaviors and self-monitoring. Based on the information derived from the self-monitoring process, individuals detect their behavioral patterns, which enables them to set goals, adjust behaviors toward goals, and evaluate their progress to goals (Bandura, 1997).

The second process of self-regulation is judgment that entails the assessment of one's behavior against goals or social norms (Bandura, 1991). Specifically, goals can be developed based on one's prior behaviors (Bandura & Jourden, 1991), or social norms that are prescribed by influential referents, such as family, friends, and peers. Through setting realistic dietary goals or behavioral referents, people can increase their confidence in achieving their goals, which ultimately leads to dietary behavior changes (Schnoll & Zimmerman, 2001). Further, by comparing progress toward set goals and receiving feedback about their actions, people can adjust their behavioral strategies to reach dietary goals, which also enhances self-efficacy (Cullen et al., 2001).

The third process of self-regulation is self-reaction that entails tangible or intangible incentives as rewards for achieving goals. Therefore, the self-reaction process helps maintain behavior change and initiate further goal setting (Cullen et al., 2001).

In addition to the three processes of self-regulation, outcome expectancy is another important dimension that affects self-regulation (Bandura, 1986). Through inducing individuals to observe their current behavior and compare it with the potential outcomes resulted from adopting a new behavior, outcome expectancy facilitates the processes of self-regulation (Bandura, 1997). Specifically, individuals are motivated to attain favorable outcomes and avoid unfavorable outcomes. Through visualizing the anticipated outcome of continuing an existing behavior or adopting a new behavior, outcome expectancy provides an incentive that drives individuals' behaviors (Bandura, 1997). That is, when informed about a potential positive outcome of a behavior, individuals are more motivated to perform that behavior. In contrast, when informed about a potential negative outcome, individuals are more likely to avoid engaging in that behavior.

The processes of self-regulation were illustrated in the "Structure of the System of Self-Regulation of Motivation and Action through Internal Standards and Self-reactive Influences" (Bandura, 1991, Figure 1). The current research adapted this structure and added the related outcome expectation construct, as shown in Table 1. The first purpose of the present study is to examine how these theoretical constructs are manifested in diet-related mobile apps. Accordingly, the following research questions are investigated.

Table 1. Conceptual and operational definitions for the theoretical constructs of self-regulation.

Theoretical constructs	Conceptual definitions	Operational definitions
Self-observation process		
Quality of monitoring: informativeness	Provision of information (quantity and quality) and feedback about one's performance and progress toward goals (Bandura, 1991)	App records the valence (healthy or unhealthy) of a diet-related behavior.
		App records the amount of calorie intake or nutrient consumption.
		App records the time or the duration of a dietary behavior.
Quality of monitoring: accuracy	The extent to which monitoring is free from subjective bias	The extent to which the app correctly records the nutrition or food: high accuracy (barcode scanning), moderate accuracy (database selection), low accuracy (self-report in text/photo).
Quality of monitoring: proximity	The extent to which self-monitoring is close in time to the observed behavior	Time span between the dietary behavior and recording: close proximity (recording immediately before/after the dietary behavior); distal proximity (recording the dietary behavior in flexible time spans).
Quality of monitoring: regularity	Behavior is observed on a continuous basis rather than intermittently (Bandura, 1991).	App features reminder or push notification that reminds users to record dietary behaviors.
Judgment process		
Personal standards Explicitness	Specificity (Bandura & Cervone, 1983) through quantification (percentage) or enumeration	App allows setting specific goals that are numerated or quantified.
Proximity	How far into the future goals are projected (Bandura & Simon, 1977)	App allows setting long-term goal (more than 6 months).
		App allows setting short-term goal (less than 6 months).
Referential performance		
Social comparison	Comparison to presumably similar people, which implies conformity with the values of social networks/groups (Bandura, 1998)	App allows users to compare their behaviors (food choice, calorie, or nutrients consumption) to other users.
Self-comparison Performance determinants	An internal process that compares the current self vs. ideal self (Neal & Carey, 2004). It also includes compare one's performance to his previous attainment (Bandura, 1991).	App allows users to compare their current behaviors to previous behaviors in a single interface.
Friends and family Experts	It is an external determinant that depends on external support or special situational assistance (Bandura, 1998). Support can be from social groups (family & friends) or professionals (Bandura, 1998).	App presents statistics to allow users to compare their behaviors to goals.
		App presents pictures (e.g., charts, bars) to allow users to compare their behaviors to goals.
		App allows receiving feedback from friends and family.
		App allows receiving feedback from experts
Self-reaction process		
Tangible rewards	People reward themselves with concrete incentives such as recreational activities, relaxing time and breaks (Bandura, 1991).	App provides tangible rewards (e.g., coupons, gifts, discounts) for users to fulfill dietary-related behavior.
Intangible rewards	Self satisfaction that serves as self motivators (Bandura, 1991).	App provides intangible rewards (e.g., points, virtual badges, trophies, congratulatory comments) for users to fulfill dietary-related behavior.
Outcome expectations		
Outcome	It is the anticipated consequences produced by a given behavior (Bandura, 1986).	App provides calorie or nutrient information about specific food.
Outcome judgment	The value placed on an outcome that can be either positive or negative (Bandura, 2004).	App provides judgment (e.g., scores, traffic lights) on specific food.

RQ1: How do commercially available diet-related mobile apps incorporate the overarching features supported by the self-regulation aspect of social cognitive theory?

RQ2: How do commercially available diet-related mobile apps incorporate features of self-observation process of self-regulation?

RQ3: How do commercially available diet-related mobile apps incorporate features of the judgment process of self-regulation?

RQ4: How do commercially available diet-related mobile apps incorporate features of the self-reaction process of self-regulation?

RQ5: How do commercially available diet-related mobile apps incorporate features of the outcome expectation construct?

USDA Dietary Guidelines for Americans, 2010

Every 5 years, the U.S. Department of Agriculture and the U. S. Department of Health and Human Services release an updated version of the Dietary Guidelines for Americans. The guidelines provide evidence-based recommendations for Americans aged 2 years old and older to adopt healthy eating behaviors. According to the USDA Dietary Guidelines for Americans, 2010, healthy eating behaviors involve self-monitoring of food consumption, regulating calorie intake, and increasing nutrient-dense food and beverage consumption. Research has provided preliminary support that using the USDA Dietary Guidelines to design interventions can enhance health outcomes (Kalarchian et al., 2013). Because of the evidence-based nature of the USDA Dietary Guidelines and its effectiveness in improving health outcomes, the extent to which a diet-related app follows the dietary recommendations may indicate how scientifically this app is designed. Therefore, this study adopts the USDA Dietary Guidelines as additional evaluation criteria to examine the design of diet-related apps. In fact, the USDA Dietary Guidelines have been used to content analyze weight loss mobile apps (Breton et al., 2011). It is also worth noting that many studies used the USDA Dietary Guidelines along with the social cognitive theory to design effective behavioral change interventions (Andrew, Borriello, & Fogarty, 2013). Therefore, the second purpose of the study is to examine how these evidence-based practices are manifested in diet-related mobile apps.

RQ 6: How do commercially available diet-related mobile apps incorporate features supported by the evidence-based USDA Dietary Guidelines for Americans, 2010?

Method

This study content analyzed 400 diet-related iPhone apps available in the Apple iTunes App Store. The unit of analysis was an individual iPhone app. Based on the apps' descriptions and screenshots, two coders separately assessed each app to determine the incorporation of theoretical constructs related to self-regulation and the USDA evidence-based guidelines. Additionally, the coders coded the basic information of each app, including price, star rating, the number of ratings, and the number of reviews.

Selecting apps for review

Apps for the iPhone were identified in August 2013 by searching the "Health and Fitness" and "Food and Drink" categories in the Apple iTunes App Store. In each category, the search terms included "diet calorie counting," "nutrition," and "healthy eating." This search process, restricted to iPhone apps, yielded 1,235 apps.

After the initial search process, the researchers conducted three rounds of screening by applying the inclusion and exclusion criteria. An app was included if it contained the functions of monitoring, judging, or providing information about calorie intake or nutritional balance from food, drinks, or supplements. An app was excluded if it was (a) a duplicate (e.g., a free version of a paid version, or sharing the same descriptions and screenshots of another app); (b) no longer existing at the time of screening or actual coding; (c) focused on special populations (e.g., pregnant women) or nutrition (e.g., uric acid); (d) not related to nutrition or dietary behaviors (e.g., focused on physical activity); (e) not in English; or (f) focused on pets. As a result, the final population consisted of 400 apps.[1]

Coding procedure

Each iPhone app was coded based on its descriptions and screenshots. Prior to the formal coding, three rounds of training were conducted with the two coders. The coders were trained on 45 apps randomly selected from the excluded free apps, which had paid versions eligible for content analysis. The formal coding occurred in January through March 2014. Then the two coders each coded all 400 apps. The two coders met to discuss and resolve the discrepancies and the results were reviewed by the third author. Table 1 summarizes the coding instrument. Intercoder reliability was calculated based on both coders' coding results from all 400 apps using Cohen's kappa: behavioral valence (.83), amount (.94), time/duration (.94), accuracy (.92), proximity (.92), regularity (.89), outcome (.92), outcome judgment (.95), goal setting (.94), explicitness (.95), goal proximity (unidentified[2] for distal goal, .93 for proximate goal), social comparison (.69), self comparison (.93 for historical comparison, .91 for behavior and goal comparison in statistical formats, and .91 for behavior and goal comparison in visual formats), personal determinants (.95 for support from friends and family, and .80 for feedback from experts), and self-reaction (1.00 for tangible rewards, and .89 for intangible rewards).

Results

Basic information about diet-related apps

Among the 400 apps in the analysis, 62.3% were paid apps (n = 249). The average price of a paid diet-related app was \$2.36 (SD = 3.60). Only 1 in 3 apps received star ratings (35.5%, n = 142), and the average rating was 3.3 out of 5 (SD = 1.12). On average, an app received ratings from 76 users (SD = 287.59) with 25.82 reviews (SD = 134.14). This noticeable difference in the standard deviation suggested that some popular apps attracted hundreds of users to give ratings and reviews, while others failed to do so.

Apps featuring theoretical constructs

RQ1 asked the extent to which the features of apps exhibit the prevalence of self-regulation theoretical constructs. Among all the eligible apps, 72.5% (n = 290) incorporated at least one of the self-regulation constructs. Specifically, 58% (n = 232) featured self-observation and 64% (n = 256) featured judgment process. However, only 9.5% (n = 38) featured self-reaction.

On average, the diet-related apps incorporated approximately 6 theoretical constructs (M = 5.5, SD = 3.6). The minimum number of theoretical constructs incorporated in an app was 1, and the maximum number was 13. The apps that contained 13 theoretical constructs were "Rate what I ate:

[1]Due to page limit, the flow diagram of the selection process of the diet-related iPhone apps is not included but is available upon request to the corresponding author.

[2]The two coders both agreed that no eligible app featured distal goal. Because the coding for this feature is invariant, Cohen's kappa cannot calculate the reliability of distal goal.

Photo diet tracker and motivation"; "Hungry cat: A calorie counter providing fun and motivation"; "Meallogger: Photo food journal, personal diet diary and social nutrition network"; and "Diet and weight loss track by calorie count."

Self-observation process

To answer RQ2, this study examined how diet-related apps incorporated the specific dimensions of self-observation for monitoring. The informativeness subdimension involved whether an app records the quality (i.e., behavioral valence) or quantity (amount and time/duration) of a diet-related behavior. In terms of behavioral valence, very few apps prescribed and recorded whether a diet-related behavior is healthy (1.8%, *n* = 7), unhealthy (0.5%, *n* = 2), or both (4.8%, *n* = 19). The remaining apps either did not record behavioral valence (i.e., coded as "no") or lacked any recording features (i.e., coded as "not applicable").[3] Almost half of the apps recorded the amount of calorie or nutrient consumption and the time (55.0%, *n* = 220) or duration of diet-related behaviors (55.3%, *n* = 221).

In terms of accuracy, moderate accuracy (i.e., choosing from a built-in database) was the most prevalent level, and was found in 32.5% (*n* = 130) of all the eligible apps. Only 3.5% (*n* = 14) of the apps allowed users to record calorie or nutrient consumption in high accuracy through barcode scanning. Seventy-one apps (17.8%) allowed users to self-report or take photos of food consumption (i.e., low accuracy). For proximity, the timing between performing and recording a behavior, 51.3% (*n* = 205) of the apps allowed users to record their diet-related behaviors in a distal proximity fashion—either before or after the food consumption in a flexible time span. Twenty-three apps (5.8%) featured close proximity—recording either immediately before or after the diet-related behaviors. Specifically, 5.5% of the eligible apps only allowed users to record their diet-related behaviors before food consumption through photos, and hence recording had to precede food consumption, and one app (0.3%) required users to record their behaviors immediately after consumption since it counted the time duration of consuming food. In addition, only 3.5% (*n* = 14) of the apps incorporated a feature that reminds users to regularly record their diet-related behaviors, such as an alarm.

Judgment process

Since the judgment process involved the subdimensions of personal standard, referential performance, and personal determinant, RQ3 examined how diet-related apps incorporated these three subdimensions related to the assessment of one's behavior against goals or social norms.

To evaluate the presence of personal standard, this study examined goal explicitness and proximity. In terms of explicitness, 53.5% (*n* = 214) allowed users to set an explicit and quantified goal for weight loss or diet-related behavior, such as calories and food groups/nutrients. In terms of the proximity of a diet-related goal, none of the apps allowed users to set a long-term goal (for at least 6 months), and 55.3% (*n* = 221) allowed users to set short term goals (e.g., daily, weekly, or monthly).

Among the 400 apps, very few included social comparison (3%, *n* = 12), such as allowing users to compare their calorie or nutrients consumption to other users. However, many included self-comparison, facilitating users to compare their current to previous diet-related behaviors (22.5%, *n* = 90) in a single interface. Many apps also included self-comparison in terms of current behavior versus goal. The most common form was current behavior versus goals presented in statistical formats (32.8%, *n* = 131), followed by current behavior versus goals presented in visual formats such as bars or lines (29.3%, *n* = 117). For performance determinant, 5.3% (*n* = 21) allowed users to receive feedback from their friends and family, and 4.5% (*n* = 18) allowed users to receive feedback from experts.

Self-reaction process

RQ4 examined how diet-related apps incorporate self-reaction in terms of rewards for achieving goals. Only 2.3% (*n* = 9) featured tangible reward, such as Amazon coupons or discounts, and 8.3% (*n* = 33) featured intangible reward, such as virtual badges or trophies.

Outcome expectation

RQ5 explored the extent to which apps incorporated outcome expectation. The results showed that most of the apps featured at least one component of outcome expectation (79.7%, *n* = 319). Specifically, 76.8% (*n* = 307) contained nutrition information about expected outcomes of consuming a specific food. However, only 1 in 5 apps provided nutrition judgment (e.g., traffic light or scores) to users about whether a specific food was healthy or not (20.3%, *n* = 81).

Apps featuring evidence-based practices

RQ6 explored how diet-related apps incorporate the recommendations of the Dietary Guidelines for Americans (USDA, 2011). The results showed that while more diet-related apps recorded users' nutrient consumption (50.5%, *n* = 202) than calorie intake (36.8%, *n* = 147) for self-observation and monitoring, they equally emphasized setting goals for calorie intake (35%, *n* = 140) and nutrition consumption (35.5%, *n* = 141) for the judgment process.

Agreement between descriptions and actual apps

Like previous content analysis studies of mobile apps (e.g., Breton et al., 2011; West et al., 2012), the coding of the app features was based on the descriptions and screenshots provided by the developers to the App Store. It is likely that there might be discrepancies between the description and screenshots and the actual app. To examine the agreement between apps' descriptions and actual apps' features, this study downloaded and coded about 10% of the apps and compared the coding based on the

[3]In the following Results section, the remainder of the apps that are not reported either did not contain the focal feature (coded as "no"), were unclear to judge the level of feature they contain (coded as "unclear"), or lacked the overarching feature (coded as "not applicable"). The coding scheme is available upon request.

descriptions and the actual apps, following Breland et al. (2013). In June 2014, 41 apps were randomly sampled from all the eligible apps based on the free versus paid stratification (17 for free apps, and 24 for paid apps). The two coders who originally coded the descriptions of all 400 eligible apps coded the actual apps. In order to capture the features of the actual apps, the coders simulated the use of the apps by entering a week's worth of fabricated data into the apps.

As Table 2 displays, the agreement between the description pages and the actual apps was high to moderate except for self-comparison, performance determinant, and judgment outcome. There was no statistical significance between the two groups in terms of their prices, star ratings, number of raters, and number of reviews. These results suggested that the downloaded subset of apps was representative of all the eligible diet-related apps.

We also compared how the description and the actual apps differed. Table 3 presents the agreement between the apps' descriptions and downloaded apps in terms of theoretical constructs and the 2010 USDA Dietary Guidelines. The overall percentage of agreement was 85.67%, and the percentage of agreement for each variable varied from 65.85% to 100%. These results were consistent with Breland et al. (2013), who reported that the percentage of agreement between the description and downloaded apps ranged from 65.2% to 95.7% in the seven constructs the author examined.

Furthermore, this study examined the extent to which the apps' descriptions under- or overreport actual app features. Based on the definitions of Breland et al. (2013), underreporting of app features involves the situation where either (a) the features are absent in the app description page but present in the actual app, or (b) the actual app features more sophisticated functions than its description. In contrast, overreporting of app features involves the situation where either (a) the features are present in the app description page but absent in the actual app, or (b) the actual app features less sophisticated functions than its description. As Table 3 displays, the percentages of underreporting ranged from 0 to 17.1%, and the percentages of overreporting ranged from 0 to 14.6%. The inconsistencies between the descriptions and the actual apps did not necessarily mean that app developers overstated their apps' features. As Table 3 presents, the description pages not only overreported but also underreported the presence of an app feature. There was one exception in that description pages tended to overreport different apps' abilities to allow users to compare their dietary-related behaviors to their families' and friends' behaviors. This function was absent in the actual apps.

Discussion

This study identified all the diet-related apps in the Apple iTunes App Store as of August 2013. Theoretical constructs in social cognitive theory, in particular, those related to self-regulation (i.e., self-observation, judgment process, self-reaction, and outcome expectation), were employed to guide this content analysis in examining whether the publicly available diet-related apps incorporate theory-supported features. Additionally, these diet-related apps were compared against the 2010 USDA Dietary Guidelines for Americans to demonstrate whether comprehensive, balanced, and scientifically validated dietary practice guidelines were present in these apps. This theory-based content analysis demonstrated that a majority of these apps included at least one feature that could be justified by the theoretical constructs related to the self-regulation processes. However, very few apps (5.5%, $n = 22$) actually incorporated features that covered all the three self-regulation processes (self-observation, judgment process, and self-reaction), mainly due to the lack of attention to the self-reaction process in these diet-related apps. The outcome expectation construct was also prevalent in these apps. A particularly promising finding was that these diet-related apps had equal emphasis on calorie limit and food groups or nutrients, which is consistent with the 2010 USDA Dietary Guidelines for Americans. The equal emphasis on calorie intake and nutrition consumption showed an improvement from the weight loss apps that mostly focused on calorie limit (Breton et al., 2011). In the following section, we discuss the findings related to the major theoretical constructs and the USDA evidence-based guidelines as well as their implications. We conclude by summarizing our contributions and limitation.

First, regarding the self-observation process of self-regulation, our content analysis focused on quality of monitoring, including informativeness, regularity, proximity, and accuracy. One striking finding was that among the 230 apps that included self-observation features, only 28 apps incorporated features to indicate behavior valence—how good the outcome of the observed behavior is. We speculate that the difficulty in assigning a clear valence indicator might contribute to such a low presence of the behavior valence feature. It is hard to indicate whether one particular food is good or bad because it needs to be assessed in relation to all food items an individual consumes. Currently, there are a number of simple indicators available, such as the Overall Nutritional Quality Index (ONQI) (Katz et al., 2009) and the traffic light system (Epstein, 1996). Future diet-related app designers might consider utilizing such scientifically validated systems to provide behavioral valence indicators.

For the accuracy of self-observation, the majority of apps enable low to moderate levels of recording accuracy. The app can provide accurate information for self-observation if it allows the users to scan the universal product code of the packaged food. For fresh produce, the most convenient option is to choose

Table 2. Comparison of general features between apps coded from description ($N = 359$) and downloaded apps ($N = 41$).

Features	Eligible apps	Downloaded apps	p
Price	1.51	1.04	.35
Star rate	1.15	1.34	.50
Number of people rating	26.97	27.27	.99
Number of reviews	15.47	18.88	.85

Table 3. Agreement between descriptions and downloaded apps for theoretical constructs (N = 41).

Theoretical constructs	Percentage of agreement (%)	Kappa	Percentage of underreporting (%)	Percentage of overreporting (%)
Self-observation				
Informativeness				
Quality*	85.37	.67	2.56	7.70
Quantity				
Amount	85.37	.63	9.76	4.88
Duration	87.80	.64	2.43	9.76
Accuracy	73.17	.61	14.63	12.20
Proximity	85.37	.63	7.32	7.32
Regularity	90.24	.55	9.76	0
Judgment process				
Personal standard				
Explicitness	85.37	.68	4.88	9.76
Proximity				
Long-term goal	100	Undefined	0	0
Short-term goal	85.37	.66	4.88	9.76
Referential performance				
Social comparison	97.56	.66	0	2.43
Self-comparison				
History*	65.85	.49	17.50	15.00
Goal (statistical formats)*	70.73	.51	15.00	12.50
Goal (visual formats)*	65.85	.43	15.38	15.38
Performance determinant				
Family and friend	82.93	.13	2.43	14.63
Expert	95.12	.47	4.88	0
Self-reaction				
Tangible reward	100	Undefined	0	0
Intangible reward	97.56	.79	2.43	0
Outcome expectations				
Outcome	82.93	.63	12.20	4.88
Outcome judgment	82.93	.43	4.88	12.20

Agreement between descriptions and downloaded apps for Dietary Guidelines for Americans (2010) recommendations (N = 41)

Recommendations	Percentage of agreement (%)	Kappa	Percentage of underreporting (%)	Percentage of overreporting (%)
Self-observation				
Calorie intake	95.12	.90	2.4	2.4
Nutrient consumption	85.37	.63	9.8	4.9
Judgment process				
Calorie goal	85.37	.71	7.3	7.3
Nutrient goal	80.49	.61	14.6	4.9

*For the variables quality, history, goal (statistical formats), goal (visual formats), five apps were neither overreporting nor underreporting and were not included in the calculation. Specifically, for the variable of quality, the app named "Diet Cheat" was coded as "not applicable" based on its description since it did not mention the self-monitoring function at all, but was coded as "no" based on actual app use since it featured the self-monitoring function yet did not provide quality information. The app named "Bites and Chews" was coded as "no" based on its description but coded as "not applicable" based on actual app use. For the variable of history, the app named "iFood Diary" promised to compare users' current calorie intake to previous performance in its description, yet its actual app compared weight in history rather than calorie. For the variable of goal (visual formats), the app named "NutriAid Diet Tracker, Loss Weight without Calorie Counting" promised to compare users' actual weight to their goal in its description, yet the actual app use revealed that it compared users' calorie intake to their calorie goal. Additionally, the app named "Calorie Calculator Pro" was coded as "not clear" based on its description but was coded as "no" based on actual app use. For the variable of goal (statistical formats), the app named "Calorie Calculator Pro" was coded as "not clear" based on its description page but was coded as "no" based on actual app use.

from the database included in the app, which is still somewhat cumbersome and time-consuming, especially if the databases have many entries with granular details. A number of apps allow users to upload a picture of the food. Although this is a convenient way to food journal, it does not quantify the calorie or nutrient information. This suggests that there may be a tension between accuracy and convenience in self-observation. It is recommended that app designers consider providing multiple options with varied levels of recording accuracy and convenience to accommodate users' needs. For instance, the app could allow users to choose from a database with granular details if the user's priority is accuracy, or the app could allow users to choose from a simplified database with fewer options if users prioritize convenience. We also found that very few apps included features that promote regularity of self-observation. Push notifications could be employed to remind users to monitor their behaviors. How to design push notifications that are unobtrusive and effective is critical for these apps.

The second process of self-regulation is the judgment process. The current content analysis examined whether diet-related apps include features with personal standard (explicitness and proximity of goals), referential performances (social comparison and self comparison), and performance determinants (external determinants). For personal standard, we specifically examined whether the apps allow users to set explicit goals, proximate goals, and distant goals. More than half of the apps featured explicit goal setting. More importantly, equal emphasis on calorie goal and nutrient goal was found, suggesting that the diet-related apps in Apple's App Store were congruent with the USDA Dietary Guidelines for Americans, 2010. Interestingly, none of the apps facilitated distal goal setting, that is, 6 months or more, which is understandable as setting diet goals is typically based on a daily or weekly plan.

Very few diet-related apps incorporated features allowing social comparison for referential performance. As our results showed, very few apps included features that allowed users to involve friends, family, or experts in the judgment process of self-regulation. A focus-group study with young and healthy individuals found that social media features were considered as unnecessary and off-putting for health behavior change using smartphone apps (Dennison, Morrison, Conway, & Yardley, 2013). With this limited evidence, it seems that excluding social comparison via social media in the apps is a wise approach. Although social comparison might enable self-judgment, the empirical question that needs further research is whether users are willing to share their personal eating behavior information for social comparison. It might be worth investigating with whom diet information sharing for social comparison might be optimal.

Our data showed that the majority of the diet-related apps facilitated self-comparison. These apps had a variety of means to enable self-comparison, including comparing current self-behaviors with previous behaviors, and comparing current behaviors with goal behaviors. Most of the apps that include self-comparison features leveraged data visualization, enabling users to clearly see previous trend and self-comparison data at a glance. Visualization is a particularly useful technique that helps people interact with and make sense of the underlying data (Bainbridge, 2004). Visualized data of self-behaviors enable individuals not only to judge their behaviors but also to infer the pattern of their behaviors, which potentially may help them associate their behaviors with certain contexts. Once individuals identify the triggers or contexts of their behavior patterns, they may better regulate their behaviors. It is recommended that app designers take advantage of the smartphones' capacity to generate visualized data for referential performance.

Compared to features that supported self-observation and judgment processes, very few apps included features of self-reaction—the positive or negative response to a given behavior. Among the 400 diet-related apps, nine apps provided tangible rewards, and 33 apps provided intangible rewards. Rewards can provide encouragement and incentives that motivate and reinforce self-regulation (Bandura, 1991). It is clear from the analysis of the existing diet-related apps that the self-reaction process of self-regulation is relatively neglected. It is recommended that future app designers consider including features to support self-reaction.

Self-regulation has been frequently adopted as a theoretical framework for behavior change interventions (Anderson et al., 2007; Burke et al., 2011). However, few studies elaborate on how the three processes of self-regulation are built into an intervention. This content analysis provides a comprehensive operationalization of self-regulation in the area of diet management, which can inform the development of theory-based intervention by researchers and practitioners in the domain of diet and weight management. It is worth noting that mobile app designers might not have intentionally integrated the theoretical constructs when developing diet mobile apps. However, there is a need for cooperation between app developers and researchers to design apps' features guided by a theoretical framework, given the evidence that theory-driven interventions are more effective in promoting health behavior change (Glanz & Bishop, 2010).

A particularly promising finding was that these diet-related apps had equal emphasis on setting goals for limiting calories and setting goals for food group or nutrient intake. This practice in diet-related apps demonstrates an improvement from weight-loss apps that mostly focus on calorie regulation and overlook nutrient intake (Breton et al., 2011). As the USDA Dietary Guidelines for Americans 2010 proposes, eating a healthy diet involves both maintaining calorie balance and consuming nutrient-dense food. Admittedly, the equal emphasis on nutrient and calorie intake in apps does not necessarily mean that app developers mindfully follow the USDA recommendations. Furthermore, allowing users to set calorie and nutrient goals does not necessary mean that such goals meet the dietary standards of USDA guidelines. Therefore, health communication scholars can play an important role in educating app developers on mindfully incorporating the USDA dietary recommendations in the diet-related apps.

The current study has a number of limitations. First, we only examined the Apple iTunes App Store and did not investigate the Google Play apps store. Although many of the apps have both versions, there may be unique apps in the Google Play store that this study did not cover. Second, we followed the 2010 USDA Dietary Guidelines for Americans to code whether the diet-related apps enabled self-regulation of calories and balanced food groups/nutrients. However, we did not break down the nutrients into smaller categories. Future research can examine how diet-related apps facilitate a user regulating consumption of specific nutrients. Third, the content analysis was based on descriptions provided by the app developers, which might not accurately represent the actual content of the apps. One way to address this issue is to analyze the apps based on actual use. However, this approach is still not perfect because a feature may be present in the app but a user might not notice it. The feature also might be used differently by different users. Although this issue is innate for content analysis of interactive media, we attempted to address this issue by downloading 41 of the 400 included apps and comparing the coding based on description and actual app use. The content analysis of the actual apps' features was accomplished by simulating the actual use. The comparison revealed acceptable overall agreement and kappa values for most of the coding categories, except for the coding of performance determinant.[4] The results showed both underreporting and overreporting. Therefore, the readers need to interpret the findings with this limitation in mind.

[4]As a conservative measure, Cohen's kappa over .40 may be considered acceptable (Fleiss, 1981; Landis & Koch, 1977). However, typically kappa over .60 or .70 is considered as good reliability. In our coding, the percentage of agreement was relatively high (82.93% for friends and family and 95.12% for expert). However, the majority of the agreements between two coders were based on the concurrence on a feature/category that was either absent or present. When a large number of absent cases and a small number of present cases exist, even very few disagreements for the coding of presence can bring down the value of kappa dramatically (for an example, see Figure 4 in Krippendorff, 2004).

In conclusion, this theory-based and evidence-based content analysis contributes to the literature in the following ways: First, most of the existing literature on mobile diet-related apps focuses on weight loss. We broadened this scope by including the apps that support healthy eating behaviors. Second, our content analysis is based on a consistent theoretical framework and the evidence-based USDA Dietary Guidelines, which have been verified in many successful healthy eating interventions. Although some content analyses of health and fitness apps are also based on theories (e.g., Azar et al., 2013), these studies did not examine specific theoretical constructs. This content analysis was based on the self-regulation aspect of the social cognitive theory and examined the granular details of how each construct in the three processes of self-regulation manifested in the apps' features. Third, instead of selecting only a fraction of the apps, we did a systematic search of all the diet-related apps. Therefore, this study can provide a more comprehensive picture of all the publicly available diet-related apps. The findings of this study can guide app designers to better utilize theories in designing health- or fitness-related apps to promote healthy behavior based on the processes of self-regulation. The findings can also guide users and researchers to select apps that encompass the optimal features for future interventions.

ORCID

Nagwan R. Zahry 0000-0003-3454-8763

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