Towards an Effective Health Interventions Design: An Extension of the Health Belief Model

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Abstract

Introduction: The recent years have witnessed a continuous increase in lifestyle related health challenges around the world. As a result, researchers and health practitioners have focused on promoting healthy behavior using various behavior change interventions. The designs of most of these interventions are informed by health behavior models and theories adapted from various disciplines. Several health behavior theories have been used to inform health intervention designs, such as the Theory of Planned Behavior, the Transtheoretical Model, and the Health Belief Model (HBM). However, the Health Belief Model (HBM), developed in the 1950s to investigate why people fail to undertake preventive health measures, remains one of the most widely employed theories of health behavior. However, the effectiveness of this model is limited. The first limitation is the low predictive capacity ($R^2 < 0.21$ on average) of existing HBM's variables coupled with the small effect size of individual variables. The second is lack of clear rules of combination and relationship between the individual variables. In this paper, we propose a solution that aims at addressing these limitations as follows: (1) we extended the Health Belief Model by introducing four new variables: Self-identity, Perceived Importance, Consideration of Future Consequences, and Concern for Appearance as possible determinants of healthy behavior. (2) We exhaustively explored the relationships/interactions between the HBM variables and their effect size. (3) We tested the validity of both our proposed extended model and the original HBM on healthy eating behavior. Finally, we compared the predictive capacity of the original HBM model and our extended model.

Methods: To achieve the objective of this paper, we conducted a quantitative study of 576 participants' eating behavior. Data for this study were collected over a period of one year (from August 2011 to August 2012). The questionnaire consisted of validated scales assessing the HBM determinants – perceived benefit, barrier, susceptibility, severity, cue to action, and self-efficacy – using 7-point Likert scale. We also assessed other health determinants such as consideration of future consequences, self-identity, concern for appearance and perceived importance. To analyses our data, we employed factor analysis and Partial Least Square Structural Equation Model (PLS-SEM) to exhaustively explore the interaction/relationship between the determinants and healthy eating behavior. We tested for the validity of both our proposed extended model and the original HBM on healthy eating behavior. Finally, we compared the predictive capacity of the original HBM model and our extended model and investigated possible mediating effects.

Results: The results show that the three newly added determinants are better predictors of healthy behavior. Our extended HBM model lead to approximately 78% increase (from 40 to 71%) in predictive capacity compared to the old model. This shows the suitability of our

extended HBM for use in predicting healthy behavior and in informing health intervention design. The results from examining possible relationships between the determinants in our model lead to an interesting discovery of some mediating relationships between the HBM's determinants, therefore, shedding light on some possible combinations of determinants that could be employed by intervention designers to increase the effectiveness of their design.

Conclusion: Consideration of future consequences, self-identity, concern for appearance, perceived importance, self-efficacy, perceived susceptibility are significant determinants of healthy eating behavior that can be manipulated by healthy eating intervention design. Most importantly, the result from our model established the existence of some mediating relationships among the determinants. The knowledge of both the direct and indirect relationships sheds some light on the possible combination rules.

Keywords: Health Belief, Models, Health Behavior, Health Interventions, Theories, Determinants.

Introduction

The growing increase in lifestyle-related health problems has motivated a shift from treatment-and-prescription centric (reactive) healthcare system to a patient-centric (proactive) system that is based on prevention and promotion of healthy behavior around the world. A variety of health behavior interventions have been designed with a preventive standpoint toward diseases in mind. A typical example is RightWay Café, a game designed to encourage healthy eating in young adult (Peng, W., 2009). Similarly, *LunchTime* is persuasive health application designed to teach people how to make healthy eating choices when eating in the restaurants (Orji et al., 2012). The designs of most of these interventions are informed by health behavior models and theories adapted from various disciplines. This is because interventions that are informed by theories and models tend to be more successful than those based on intuition (Glanz et al., 1997). Several health behavior theories have been used to inform health intervention designs, such as the Theory of Planned Behavior (Ajzen, I., 1991), the Transtheoretical Model (Prochaska et al. 1992), and the Health Belief Model (Rosenstock, 1966). However, the Health Belief Model (HBM), developed in the 1950s to investigate why people fail to undertake preventive health measures, remains one of the most widely employed theories in the design and evaluation of health behavior interventions (Glanz and Lewis, 2002; National Cancer Institute, 2003). The HBM was developed to address problem behaviors that evoke health concerns. It postulates that an individual's likelihood of engaging in a health related behavior is determined by his/her perception of the following six variables: *Perceived susceptibility* (perceived risk for contracting the health condition of concern); *Perceived severity* (perception of the consequence of contracting the health condition of concern); *Perceived benefit* (perception of the good things that could happen from undertaking specific behaviors); *Perceived barrier* (perception of the difficulties and cost of performing behaviors); *Cue to action* (exposure to factors that prompt action); and *Self-efficacy* (confidence in one's ability to perform the new health behavior). These six health determinants identified by HBM together provide a useful framework for designing both long and short-term health behavior interventions (Glanz, 1995). HBM focuses mainly on health determinants; therefore, it is most suitable for addressing problem behaviors that have health consequences (e.g., unhealthy eating and physical inactivity). HBM has been adapted and successfully applied in the design of health interventions (for example see Peng, W., 2009; Orji et al., 2012). However, despite the success of HBM in informing and predicting a range

of behaviors with health outcomes, previous research shows that HBM's determinants are insufficient predictors of behavior (Norman & Brain, 2005). This is due to two main limitations of HBM: the low predictive capability of the determinants; their small effect size; and the lack of clear rules for combination of the variables and the relationships between them. On average, HBM's determinants predict approximately 20% ($R^2 < 0.21$, see Cohen, 1988, 1992) of variance in healthy behavior, leaving 80% of the variance unaccounted for. This points to the need to investigate other determinants that were not accounted for by HBM. In addition, most HBM researchers assume that the individual determinants are only directly related with healthy behavior and no indirect or mediating effects exist between the variables.

In response to these two limitations, many researchers have extended the original HBM to increase its predictive capacity. For instance, *self-efficacy* was added as an extension to the original HBM (Rosenstock et al., 1988). In recent years, there has been renewed interest in adapting and extending the HBM. For example, Reece (2003), in a study of HIV-related mental health care extended the HBM to include '*HIV-related stigma*' variable. However despite these extensions, the average predictive capacity of HBM remains considerably low, ranging from 20% to 40% (Conner & Sparks, 1996; Conner & Armitage, 1998). Moreover, most of the new variable(s) added to the model are application area specific and thus only suitable for a particular health behavior domain under investigation. Therefore, the extended models may not be applicable in other health domains. Investigating other determinants that affect a range of health behaviors is essential for improving the effectiveness of health promotion intervention designs based on HBM.

To address these limitations and also further our effort towards developing an effective persuasive technological intervention for behavior change, we extend the HBM to include four new variables as determinants of healthy behavior: *Self-identity, Perceived Importance, Consideration of Future Consequences,* and *Concern for Appearance.* To test the suitability of our model, we validated it on healthy eating domain. We conducted a quantitative study on 576 participants and employed Structural Equation Modeling (SEM) to exhaustively explore the interaction/relationships between the variables of the extended HBM. As a secondary research objective, we validated the predictive capacity of the primary HBM (with *susceptibility, severity, benefit,* and *barrier* as main determinants) on healthy eating behavior. We also examined the predictive utility of *self-efficacy* alongside *cue to action* to the HBM. Finally, we compared the results from the three models (the primary HBM, the primary HBM with *self-efficacy* and *cue to action* added, and our extended HBM).

The results from our models show that the four new variables we added to the HBM are in fact better predictors of healthy behavior than all the previously proposed variables (*susceptibility, severity, benefit, barrier,* and *cue to action*). *Self-efficacy* however, remains the strongest determinant of healthy behavior in all the models, confirming its predictive utility. Our extended HBM model led to approximately 78% increase (from 40 to 71%) in predictive capacity in comparison with the old models. Most importantly, the result from our model established the existence of some mediating relationships among the variables. The knowledge of both the direct and indirect relationships sheds some light on the possible combination rules. These findings have both practical and theoretical implications which we discuss later.

The remainder of this paper is organized as follows: Section 2 reviews the Health Belief Model and some other determinants of healthy behavior. In section 3, we describe our research methodology: research approach and measurement instrument, research participants, and data validation. Section 4 contains the result analysis: test of the old model and our proposed model. In Section 5, we discuss our results and its implications. Finally Section 6 concludes the paper with future research directions.

Related Work

Behavioral and social science theories provide a basis for understanding health behavior. The Health Belief Model (HBM) has been widely adapted and applied in various health domains. Despite its popularity, the HBM has limitations, which stems from its low predictive capability. We begin this section with an overview of the Health Belief Model (HBM) and its limitations. We then discuss some other relevant health behavior determinants that could possibly extend the HBM and improve its predictive capability. This work is an effort towards designing an effective persuasive technological intervention for healthy behavior motivation.

1.1 Health Belief Model

The HBM is the first theory that was developed exclusively to explain health-related behaviors. As one of the oldest and the most widely used theories of health behavior (Glanz and Lewis, 2002; National Cancer Institute, 2003), it is regarded as the origin of systematic and theory-based research in health behavior (Hochbaum, 1992; Kharrazi, 2009). HBM was developed as a systematic method to identify, explain, and predict preventive health behavior (Janz and Becker, 1984; Rosenstock, 1974). According to Rosenstock (1966), the original goal of the developers of the HBM was to focus the effort of researchers who aim to improve public health by understanding why people do not take preventive measures to health promotion.

Since its development, HBM has been employed in a variety of public health settings over the years. For example, HBM has been applied to help increase voluntary screening rates for cervical cancer, e.g., undergoing Pap-test (Hay et al., 2003) and breast cancer, e.g., mammography;(Simon and Das, 1984), breast self-examination (Umeh and Rogan-Gibson, 2001), for smoking cessation (Li et al., 2003), contraceptive use (Lowe and Radius, 1987), osteoporosis prevention Wallace (2002), Dental-care (Chen and Land, 1986) , and healthy eating (Deshpande et al., 2009). The model's ability to explain and predict variety of health related behaviors has been validated across various domains and among wide range populations (Janz & Becker, 1984; Carpenter, 2010). The model has also been used in designing many successful health interventions (Arik and Boeijen, 2009; Kharrazi, 2009).

The HBM postulates that an individual's likelihood of engaging in a health-related behavior is determined by his/her perception of the four variables: *Perceived Susceptibility; Perceived Severity; Perceived Benefit; Perceived Barrier.* Each of these variables, individually or in combination, has been used to explain health behavior. These four variables have been broadly categorized into two main aspects of individuals' representations of health and health behaviors: *Perceived Threat* and *Behavioral Evaluation* (Abraham and Sheeran, 2005). We discuss each of these categories and their associated variables in detail below.

1.1.1 The Perceived Threat

The HBM posits that an individual is likely to perform a behavior if he/she perceives a threat from a disease or health condition. The threat perception is based on two beliefs: the *perceived susceptibility* of the individual to the disease and the *perceived severity* of the consequences of the disease for the individual.

Perceived Susceptibility refers to the probability that an individual assigns to personal vulnerability to developing the health condition. In order words, it is the subjective belief a person has regarding the likelihood of acquiring a disease or harmful state as a result of indulging in a particular behavior. Perceived susceptibility explains that people will be more motivated to behave in healthy ways if they believe they are vulnerable to a particular negative health outcome (Rosenstock, 1966). The personal perception of risk or vulnerability has been found to be an important perception in promoting the adoption of healthier behaviors (Abraham and Sheeran, 2005). Individuals vary widely in their perception of susceptibility to ill health condition or disease. Often, the higher the perceived risk, the higher the likelihood of an individual engaging in behaviors that decrease the risk. For example, the likelihood that an individual will engage in precautionary behavior to prevent weight gain (e.g. exercise and low calorie diet) may depend on how much they believe that they are at risk of obesity. Perceived susceptibility has been found to be predictive of a number of health-promotion behaviors including smoking cessation, breast self-examination, healthy dental behaviors, and healthy diet and exercise (Abraham and Sheeran, 2005). However, in general, it has been found that people often underestimate their own susceptibility to disease (Redding and Rossi, 2000).

Perceived Severity refers to how serious an individual believes the consequences of developing the health condition will be. It deals with an individual's subjective belief in the extent of harm that can be caused from acquiring the disease or unhealthy state, as a result of a particular behavior. An individual is more likely to take an action to prevent gaining weight if s/he believes that the possible negative physiological, psychological and social effects resulting from becoming obese pose serious consequences (e.g., death, physical impairment leading to other health condition, financial burden, pain and discomfort, and difficulties with family and social relationships). Specifically, if the undesirable health outcome will not have a large impact on individual's life, s/he will not be motivated to act to avoid it even when s/he is at risk. Although the perception of seriousness of any health condition may be based on medical knowledge, it may also come from one's belief about the difficulties a disease would create or the effects it would have on his or her life in general (McCormick-Brown, 1999).

1.1.2 Behavioral Evaluation

HBM also proposes that an individual is likely to perform a behavior if s/he perceives that performing the behavior will supposedly reduce the negative health outcome. The behavioral evaluation is based on two beliefs: the *perceived benefit* or *efficacy* of the target health behavior and the perceived *costs* or *barrier* to performing the target behavior.

Perceived Benefit refers to an individual's subjective opinion of the value or usefulness of enacting a health behavior to offset the perceived threat. Under perceived benefit, motivation to take action to change a behavior requires the belief that the precautionary behavior will effectively prevent the condition. The individual must perceive that the target behavior will provide strong positive benefits. Specifically, the target behavior must have the tendency of preventing the negative health outcome. For instance, individuals who are not convinced that

there is a relationship between eating and gaining weight are unlikely to adopt a healthier eating behavior for the mere purpose of reducing their chances of getting obese.

Perceived Barrier refers to an individual's subjective evaluation of the difficulties or the hindrances associated with the target behavior. With perceived barrier, an individual may not perform a behavior despite his/her belief about the effectiveness (benefit) of taking the action in reducing the threat if the barrier outweighs the benefit (Rosenstock, 1966). The barrier often relates to the characteristics of the health promotion measure. It may be expensive, painful, inconvenient, and unpleasant. These characteristics may lead one away from adopting the behavior. To adopt the new healthy behavior, people have to believe that the benefits by far outweigh the consequences of continuing the old behavior (Center for Disease Control and Prevention, 2004).

1.2 Extensions to the original HBM

The original HBM consisting of the four primary variables (*susceptibility, severity, benefit,* and *barrier*) has been modified my researchers. In this subsection, we discuss how the original HBM has been extended over the years with new variables

Cue to Action: In addition to the four primary variables mentioned above, Rosenstock (1966) suggests that a combination of threat and behavioral evaluation variables could reach a considerable level of intensity without resulting in overt action unless an event occurs to trigger action in an individual. Thus, *cue to action* determinant was added to the model to denote a trigger for health behavior when appropriate beliefs are held (Rosenstock, 1966). In Rosenstock's original formulation, *cues to action* could include *external cues* such as a mass media campaign, social influence, or *internal cues* such as a negative change in bodily state or perception of symptoms. More generally, cues to action can be events, people, or things that spur people to change their behavior. Although, cue to action have been identified as an important behavioral determinant, it is the most underdeveloped and rarely measured or researched variable of the model (Janz & Becker, 1984; Rosenstock, 1974)

Self-Efficacy was added to the HBM in 1988 by Rosenstock et al. It is a term that is used to describe an individual's belief about his/her ability to perform the behavior in question (Bandura, 1977). Generally, people may not want to attempt to do something new unless they think that they can do it. For instance, if someone believes that a new behavior is useful (high perceived benefit), but does not think that s/he is capable of doing it (low self-efficacy), chances are that s/he will not try the new behavior. While it seems intuitively clear that self-efficacy is a significant determinant of health-behavior following the wide adoption by health-promotion researchers, it is necessary to examine its impact in relation to other health determinants.

Table 1 presents a summary of the primary HBM constructs and the later extensions with possible strategy for applying them.

Table 1: Health Belief Model variable summary and related intervention strategies

Variables	Definition	Possible Intervention Strategy
Perceived Susceptibility	An individual's assessment of his or her chances of getting the disease	Use self-monitoring, simulation, and personalization/tailoring strategies to help individuals develop accurate perceptions of own risk.
Perceived Severity	An individual's judgment as to the seriousness of the effects of contracting the health condition	Use Systemic Desensitization, Vicarious reinforcement, and biofeedback technique to help individuals develop a realistic perception of the consequences of a condition and recommended action.
Perceived Benefits	An individual's evaluation of the positive things that will happen as a result of enacting the health behavior	Use gain-framed appeal and positive reinforcement/reward mechanism to portray the potential benefits of adopting healthy behavior.
Perceived Barriers	An individual's opinion regarding the difficulty or cost of adopting the new behavior	Teach problem solving and decision making strategies to overcome the perceived barrier of enacting healthy behavior
Cue to Action	This consist of both internal and external prompts that will trigger an individual to performing the target behavior	Employ reminder and suggestion strategies as an external prompt to performing the target behavior. Biofeedback strategy could be used as an internal trigger.
Self-efficacy	Personal belief on one's own ability to enact the desired behavior	Use role-playing, modeling, incremental goal setting strategies to build an individual's believe about his/her ability to adopt healthy behavior.

1.3 Strengths and Weaknesses of HBM

The original HBM has some recognized strengths and weaknesses which we discuss below.

Strengths

The main strength of the HBM is its use of simplified health-related constructs that make it easy to implement, apply, and test (Conner, 2010). The HBM has provided a useful theoretical framework for investigating the cognitive determinants of a wide range of behaviors for over three decades. Again, it has focused researchers' and health care professionals' attention on variables that are prerequisites for health behavior. Hence, it has formed a basis for many practical interventions across a range of behaviors (Jones et al., 1987). However, it's not without some limitations.

Weaknesses

There are two main criticisms of HBM: first, the model did not explicitly spell out the relationships between the variables and no clear rules for combining the formulated variables (Armitage and Conner, 2000; Sheeran and Abraham, 1996). However, this weakness can also be viewed as strength, because lack of strict rules of combination offers flexibility that makes the HBM adaptable and applicable to many health behavior and population groups.

The second and a major weakness of HBM is its predictive capability. The results from quantitative reviews of the HBM, suggest that the primary variables (*susceptibility, severity, benefits,* and *barriers*) were significant predictors of health-related behavior in most cases. However, their effect sizes are usually very small (Harrison et al., 1992; Abraham and Sheeran, 2005). This suggests that there are other important variables that determine healthy behavior that have not been accounted for by HBM. Thus, the model is incomplete, despite its high adoption by healthy behavior promotion researchers.

In response to this limitation, researchers have identified other variables that are probably stronger determinants of health behavior than those identified by the HBM. For instance, Rosenstock et al. (1966, 1988) extended the HBM with *cue to action* and *self-efficacy*, which generally improved the predictive power of the model. Similarly, several other researches have adapted and extended HBM in various contexts. For example, King (1982), in a study of screening for hypertension extended the HBM to include a measure of individuals *understanding* of high blood pressure. Similarly, Reece (2003) extended the HBM to access HIV-related mental health care with the addition of '*HIV-related stigma*' variable. According to Reece (2003), the addition of 'HIV-related stigma' significantly increased the model's predictive capacity from $R^2 = 0.29$ to $R^2 = 0.63$ showing again that there exist some room for improving the predictive effectiveness of HBM.

Although these researchers have attempted to improve the predictive capability HBM, most of the extended variable(s) are application area specific (only suitable for that particular health behavior under investigation). Therefore, the extended model may not be suitable for application in a range of other health behavior. Our work therefore, aims to develop an extended HBM model that can be applied across several health domains.

In summary, the HBM provides a useful framework for investigating health behaviors. In general, all the model's components are seen as independent predictors of health behavior (Armitage and Conner, 2000). High-perceived threat, low barriers, and high perceived benefits to action increase the likelihood of engaging in the recommended behavior (Berker and Maiman, 1979). However, according to Bandura (1977 as cited in Munro et al., 2007), perceived severity might have a weak correlation with health action and might even result in avoidance of protective action. The perceived severity therefore, may not be as important as perceived susceptibility. Similarly, in a review by Harrison et al (1992) susceptibility and barrier were the strongest predictors of behavior.

An individual's perception of perceived susceptibility and seriousness provide the motivation to act while benefits (minus barriers) provide the path of action. However, it may require a cue to action for the desired behavior to occur. The HBM differs from other models (e.g., the Theory of Planned Behavior (TPB)) in that there are no strict guidelines on how the different

variables combine to predict behaviors. Instead, the HBM proposes that the individual independent variables are likely to contribute to the prediction of health behaviors (Sheeran & Abraham, 1996).

Thus, HBM has been widely employed in predicting a range of behaviors with health implications. For example, Janz and Becker (1984) found that across 18 studies, the 4 primary HBM variables were nearly always significant predictors of health behavior. Susceptibility, severity, benefits, and barrier significantly predicted health behavior for 82, 65, 81, and 100% of the studies respectively. This results show that barriers and susceptibility are the most reliable predictor of behavior followed by benefits, and finally severity. This finding was further supported by the review conducted by Harrision et al. (1992) with more stringent inclusion criteria. Harrison et al. (1992) reported that susceptibility and barriers were the strongest predictors of behavior.

1.4 Other Important Health Behavior Determinants

Researchers have identified some other important variables that affect the tendency of performing a behavior. Most of these variables have not been examined in the context of any existing theoretical framework and therefore, have not been widely employed by health behavior intervention designers. In this section, we review some of these determinants that could possibly improve the predictive capability of existing health behavior theories.

Consideration of Future Consequences

One of the main difficulties one encounters when attempting to motivate people to adopt a healthy behavior is the invisible immediate and short-term benefit and consequences of many health behaviors. Health-related behaviors are often characterized by immediate effort for possible future gain. A rational decision to adopt healthy behavior may require that the value attached to the future health benefits outweigh the immediate cost in terms of time, money, or pleasure foregone to achieve longer-term health benefit (Adams, 2012). How one considers the future outcomes of the present behavior may also play a role in adoption of healthy behaviors. Given this, Strathman et al. (1994) proposed a new variable: Consideration of Future Consequences (CFC). CFC is used to measure "the extent to which people consider the potential distant outcomes of their current behavior and the extent to which they are influenced by these potential outcomes" (Strathman et al., 1994). Research suggests that CFC is a reliable, stable, and a valid predictor of a range of significant behaviors. Strathman et al. (1994) validated the CFC variable and reported internal reliability for the 12-item scale ranging from .80 to .86. Furthermore, Joireman et al. (2006) examined the relationship between CFC and some other related constructs and provided evidence for its convergent and discriminant validity. For instance, people who scored high in CFC also scored higher in delayed gratification and higher levels of conscientiousness (Strathman et al., 1994). Since its development, CFC has successfully predicted a range of behaviors, including health concern, environmental behavior, and cigarette or alcohol use (Strathman et al., 1994). Research has shown that individuals high on the CFC scale generally reported greater concern for health and lower use of alcohol and cigarettes. Similarly, subsequent research has demonstrated that individuals scoring high in CFC reported that they exercised more frequently (Uuellette et al., 2005), are more likely to get an HIV test, and less likely to engage in risky sexual practice (Dorr et al., 1999). While the validity of CFC to predict range of behaviors has been examined, promising past studies have not tested the validity of CFC within any well-known

health theoretical framework. A study by Orbell et al. (2004) was one of the few that studied CFC under an existing theoretical framework. They utilized the Theory of Planned Behavior (TPB) framework to illustrate the mediating role of CFC on TPB variables.

We propose to examine whether the CFC will affect the adoption of a healthy behavior and whether the interaction between CFC and healthy behavior is mediated by HBM determinants by integrating it into the HBM model as one of the health behavior determinants.

Self-Identity

Self-identity is another predictor of behavioral intention and actual behavior that has been suggested by identity theorists and has been empirically tested by researchers (Stryker, 1987). Self-identity is a term used in describing some salient and enduring part of one's self-perception in relation to a particular behavior (e.g., "I think of myself as a health conscious person") (Sparks, 2000). Research has shown that self-identity plays a role in motivating human behavior. For instance, according to Sparks and Gutherie (1998), individuals who perceive themselves as health conscious tend to positively associate with health behavior. There are other evidences linking self-identity to actual behavior or behavioral intention in several domains, including exercising (Theodorakis, 1994). In relation to healthy behavior, some work has identified that self-identity influences the tendency of one adopting a healthy behavior. According to Szalavitz (2012), one of the best ways to change health behavior is to change a person's self-identity. "" Szalavitz (2012), *When a smoker begins to view herself as a nonsmoker or a teen sees binge-drinking as something people like me don't do, behavior change is typically more lasting than if the person's sense of identity is not invoked.*
It has been argued that measures of self-identity can enhance models of the cognitive antecedents of behavior (Eagley and Chaiken, 1993). For example, Spark and Shepherd (1992) examined the role of identity in relation to the Theory of Planned Behavior and found that individuals who see themselves as green consumers (i.e., green identity) had stronger intentions to consume organic vegetables, and their self-identities contributed significantly to the prediction of intention over and above other TPB variables. Furthermore, Spark et al (1995) reported that self-identity had an independent predictive effect on intentions in relation to five dietary changes associated with reducing the amount of fat in the diet. Thus, self-identity has been shown in many studies to be a useful addition to TPB variables in predicting different dietary behaviors. Several other research works in domains ranging from exercise, eating behavior, to sexuality, and drug use suggests that having one's identity wrapped up in a particular behavior is a crucial motivating factor to sustaining the behavior (Szalavitz, 2012). The reverse is also possible. For example, a person whose identity and self-sense are tied directly to unhealthy behavior will likely continue performing the behavior.

Concern for Appearance

Several research findings have shown that people who are concerned about their health believe that they are responsible to engage in protective health behavior (Orji et al., 2012). However, other processes may also be operating. People may eat properly, not smoke, exercise, watch their weight, and practice other preventive health behavior for reasons unrelated to health concern. Research has shown that people are motivated by their concern for appearance, attractiveness, and popularity more than by the health consequences of their behavior (Hayes and Ross, 1987). The society tends to attach a lot of importance on an individual's physical appearance. This is evident in public media and advertising sectors where several actions and products are symbolized with physically attractive models, actors

and actresses suggesting that they are the ideal that the public should seek to achieve (Hayes and Ross, 1987). According to Kai-Yan (2002) people believe that physical attractiveness is linked to life of happiness, success, and social acceptance while fatness is associated with laziness, stupidity, and chaos. In general, physically attractive people have more positive social contacts and more success in manipulating their social environment than unattractive people (Barocas and Karoly, 1972). Concern with appearance has had a long-term research history. Several research findings have shown that concern with appearance exerts a great influence on human behavior and decision making. For example, as early as 1960's Walster et al. (1966) found in a study of 752 students that physical attractiveness emerged as the only predictor of an individual's liking for and desire to subsequently date a potential partner. Similarly, concern with appearance has successfully predicted health behavior in many domains including dieting (Hayes and Ross, 1987). Similarly, increased physical activity seems to be associated with concern about appearance. According to the analysis by Hausenblas and Fallon (2006), exercisers have a more positive body image than non-exercisers. Despite the increasing evidence of the widespread impact of appearance concern, it has not been widely adopted by health behavior promotion researchers. However, concern for appearance ought to be taken more seriously because people's feelings about their appearance can have significant effect on their self-perception, their health behavior, well-being, and even adherence to treatment. Thus concern with appearance may be a motivating factor in preventive health behaviors.

Perceived Importance

Research has shown that perceived importance could also be a significant predictor of behavior (Deshpande et al., 2009). Perceived importance, a term suggested and validated by Robin at al. (1996), describes how much value a person attaches to the outcomes of a particular behavior. It is different from perceived benefit in that benefit is more concerned with the good things that will happen as a result of performing the behavior in question to avert the threat. Perceived important on the other hand is more about the value an individual attaches to the outcomes of a particular behavior. These outcomes can be either positive (as a result of performing the desired health behavior) or negative as a result of not performing the behavior (or indulging in the unhealthy behavior). Perceived importance unlike benefit is not necessary evaluated based on its ability to prevent the threat. For example, exercising 30 minutes daily may be perceived by an individual to be of benefit (because of its ability to keep one from gaining excessive weight), however, s/he may likely not exercise if s/he perceive that the various benefits accrue to exercising as unimportant to him/her. Perceived importance has been shown to successfully predict ethical behavior intention (moral judgment) (Robin et al., 1996), dietary behavior (Deshpande et al., 2009) and Honjo and Siegel (2003) showed that perceived importance impact on weight concern and smoking initiation. The impact of perceived importance on health behavior is underexplored. Therefore further research is needed to investigate the impact of this variable on various health behaviors both independently and in the context of other known theoretical frameworks.

In summary, behavioral or social science theories provide the basis for understanding health behavior. These theories have been proposed as a framework for designing interventions, understanding how the interventions work to promote change in behavior, and for evaluating the effectiveness of interventions. However, the theories are limited by the percentage of variance in behavior they explain. Therefore, there is a need for research on other variables to account for the missing variance. On the other hand, the variables discussed above

(*consideration of future consequences, self-identity, concern for appearance,* and *perceived importance*) have been validated as independent predictors of various behaviors. However, they have not been examined in context of any known health theories to know their relationships with other variables and their ability to increase the predictive capacity of these theories. This work therefore seeks to examine the predictive capacity of these variables in the context of HBM, one of the widely employed theories of health behavior

Research Method

The data reported in this paper is part of a project aimed at designing theory-driven technological interventions for promoting healthy behavior that was approved by University of Saskatchewan ethics board. Research Approach and Measurement Instrument
This study employed a quantitative method of data collection which involved the collection of primary survey data from a large number of participants. To collect data for our model, we developed an online survey version of the HBM scale, *concern for appearance; consideration of future consequences; self-identity;* and *perceived importance* scales posted announcements in high traffic websites and forums. The survey was developed after an extensive review of HBM, their application areas and their effectiveness and was pilot tested (n=10) for refinement. We chose dietary behavior as a case study to validate our research instrument and to test our model because healthy eating is a desirable behavior with wide range of both mental and physical health implications. Good dietary behavior can delay or even prevent the onset of many diseases, including diabetes 2 diabetes and obesity. As a result, interventions aimed at modifying dietary behavior have been identified as the cornerstone treatment for these health conditions (Lau et al., 2007). Accordingly, several health promotion and diseases control programs (for example see Peng, 2009; Fujiki et al., 2008; Orji et al., 2012) are focused on promoting healthy eating and physical activity.

The survey instrument consists of questions assessing (1) participant demography; (2) *perceived benefit* of healthy eating; (3) *perceived barrier* to healthy eating; (4) *perceived susceptibility*; (5) *perceived severity*; (6) *cue to action*; (7) *self-efficacy* (8) *likelihood of healthy eating behavior* (9) *concern for appearance;* (10) *consideration of future consequences* (11) *self-identity;* (12) and *perceived importance*, where (9), (10), (11) and (12) are new variables, that we propose as extension to the HBM model.
The questions used in measuring the HBM variables (questions (2) to (8) listed above) were derived from Abraham and Sheeran (2005) and most of the questions have been validated on healthy eating by Deshpande (2009) and Sapp and Jensen (1998). All the HBM variables were measured using a 7-point Likert scale ranging from "1 = Strongly disagree" to "7 = Strongly agree". An example of a question in the *perceived susceptibility* variable category is requesting the participants to state their level of agreement with the statement "If I don't stick to a healthy diet, I will be at high risk for some diet-related diseases",

Extending HBM Variable

Following from the discussion in section 2.4, we extended the HBM model by including C*onsideration of Future Consequences*, *Concern for Appearance*, *Self-identity*, and *Perceived Importance*.

Consideration of Future Consequences (CFC) has been increasingly acknowledged as being important behavior determinant. The effect that the current health behavior and attitudes has on future health and well-being can be profound and, research has shown that consideration of future consequences impacts health behavior (Uuellette et al., 2005; Joireman et al., 2006).

CFC was measured using 12-item questions developed and validated by (Strathman et al., 1994). Respondents were required to indicate to what extent each item characterized them on a 5-point Likert scale ranging from "1 = Not at all" to "5 = Extremely well". Some examples of questions are "I often consider how things might be in the future and try to influence those things with my day to day behavior," "I only act to satisfy immediate concerns, figuring the future will take care of itself," and "I think that sacrifice now is usually unnecessary since future outcomes can be dealt with at a later time."

Concern for Appearance is included based on previous research findings that people are motivated by their concern for appearance, attractiveness, and popularity more than by the health consequences of their behavior (Hayes & Ross, 1987). Concern for appearance was measured using validated scales adapted from Hayes & Ross (1987). Typical questions for this variable ask the participants to rate how important it is for them to: "look attractive" and "have good posture". The questions were measured using a 5-point Likert scale ranging from "1 = Not at all important" to "5 = Very important".

Self-identity is used to describe one's perception about him/herself. Research has shown that self-identity plays a role in motivating human behavior. Individuals who perceive themselves as health conscious tend to positively associate with healthy behaviors (Sparks & Gutherie, 1998). We measured self-identity using a validated scale adapted from Sparks & Gutherie (1998). An example of a question in this category is "I think of myself as someone who is concerned with healthy eating". The participant states their level of agreement with each item using a 5-point Likert scale, ranging from "1 = Strongly agree" to "5 = Strongly disagree".

Perceived Importance: Research has shown that perceived importance could also be a significant predictor of behavior. Perceived importance, a term suggested by Robin et al. (1996), describes how much value a person attaches to the outcomes of a particular behavior. It was added following research from Deshpande et al. (2009) that showed that perceived importance is a determinant of healthy eating. Perceived importance was measured using a validated scale adapted from Deshpande et al. (2009). A typical question is "How important is it for you to eat a diet high in nutrition?" The questions were measured using a 5-point Likert scale ranging from "1 = Not at all important" to "5 = Very important".

1.5 Research Participants

The participants consisted of 576 adults recruited from the Internet. There were 559 usable responses (responses from participants that are at least 18 years of age). The data were gathered over a period of eleven months in from August 2011 to August 2012. The eligibility criterion was that the participants were at least 18 years old at the time of data collection. The eligibility criterion was in compliance with the study ethics approval that ensured that the participants were of legal age to make decisions independently (including decisions on what to eat). The participants' demographics is as summarized in Table 2.

Table 2: Summary of participants' profile

Variable		Frequency (n = 559)	Percent (%)
Gender	Female	269	48
	Male	290	52
Age	18-25	196	35
	26-35	203	36
	36-45	77	14
	Over 46	83	15
Education	Less than high school		
	High school graduate	76	14
	College diploma	69	12
	Bachelor's degree	189	34
	Master's degree	165	30
	Doctorate degree	40	7
	Others	14	2
Geographical Territory	Africa	181	32
	North America	176	32
	South Asia	124	22
	Western Europe and UK	39	7
	Middle East	11	2
	South and Central America	6	1
	East Europe and Russia	4	1
	Southern Europe/Mediterranean	8	1
	Australasia	1	0
	Others	9	2

1.6 Data Validation

To ensure reliability and validity, we selected an analytical method that explicitly models the linear and quadratic effect (non-linear relationships) between the measured variables. We used both SPSS 19 and SmartPLS 2 (Ringle et al., 2005) Structural Equation Modeling (SEM) tool to exhaustively explore the interaction between the variables and to simultaneously solve the multiple equations.

Instrument Validation: To determine the validity of the survey instrument we conducted Principal Component Analysis (PCA) using SPSS 19. Before conducting PCA, the Kaiser-Meyer-Olkin (KMO) and Bartlett sphericity tests were used to measure the sample adequacy (Kaiser, 1970.). The KMOs were all greater than the recommended threshold of 0.5 and the result of Bartlett sphericity tests were significant at <0.001. Thus, the data was suitable to conduct factor analysis (Guo, 1999). The factor loadings and the corresponding factor scores (weights) for each variable were generated. The factor loading resulted in removal of some questions and the remaining questions have larger loading on their corresponding factor (≥0.7) than cross-loadings on other factors (≤0.4) (Gefen et al., 2000). Thus, these questions

could effectively reflect factors because they have good validity including convergent and discriminant validity.

Reliability of the Variables and Indicators: We examined the data for reliability using both SPSS and SmartPLS tool. To check the reliability, we used Cronbach's α, which ranges from 0 to 1. According to Peter (1997), Cronbach's α should be ≥ 0.7, but for 2-3 indicator variables, a Cronbach's α ≥ 0.4 is acceptable. As shown in Tables 3 (column 4), the Cronbach's α of the variables satisfies these conditions (susceptibility and severity have two indicators each, therefore, their Cronbach's α are within the acceptable range of ≥ 0.4)

Results Analysis

After the validation of the data, we developed and tested the path model presented in Figures 1, 2, and 3 using SEM in SmartPLS tool, which allows for simultaneous measurement (of indirect and direct influences of the variables) and structural models. In contrast to previous work in which SEM was used to confirm or test hypotheses, our goals are:

1) to validate our extended HBM in the healthy eating behavior domain;

2) to test the predictive capability of the extended HBM model by generating a predictive model of healthy eating;

3) to exhaustively examine the interactions between the extended HBM variables and the original HBM variables;

4) to validate the old HBM and confirm its performance on healthy eating behavior, and

5) to compare the predictive capability of the original HBM variables and the extended HBM variables.

To achieve these aims, we systematically examined the interactions and the impact of the 10 variables (*susceptibility, severity, benefit, barrier, cue to action, self-efficacy, perceived importance, consideration of future consequences, appearance concern,* and *self-identity*) on healthy behavior. This enabled us to exhaustively explore the importance of each variable in determining healthy eating behavior. We chose to validate our model on eating behavior because it is associated with many health implications.

1.7 Test of Proposed Path Model

Partial Least Square (PLS) model analysis essentially proceeds through two stages. The first stage deals with reliability and discriminants validity analysis of the indicator items and their associated independent variables in the outer model. In the second stage, the relationships between the dependent variables in the inner model are estimated through bootstrapping procedures. Our analysis rigorously followed these two stages to confirm both discriminate and convergent validity and internal consistency. The model fit indices of the structural equation model are presented in Table 3. The square root of Average Variance Extraction (AVE) coefficients from the SmartPLS output is a key statistic at the first stage of the path analyses as it represents the variance extracted by the variable from its indicator items. As

shown in Table 3, the AVE indices for all the variables are above the ideal value of 0.5. The Cronbach's α values and the composite reliability that analyzes the strength of each indicator's correlation with their variables are all higher than their threshold values. Specifically, the high Cronbach's α values of our newly added variables of *consideration for future consequence, perceived importance, self-identity,* and *appearance concern* (0.81. 0.87, 0.88, and 0.80 respectively) shows suitability. Similarly, redundancy values are greater or equal to "0". The t-values that measure the significance of the path coefficient are all greater than the recommended threshold value of 1.96. All the interactions (path models) presented in the models are statistically significant at p≤ 0.01. Overall, our proposed model's variables predict 71% of variance in healthy eating behavior (see Figure 1). This shows the high predictive relevance and the suitability of the extended HBM.

To measure the shared variance between the variables and their measures, we evaluated the discriminate validity of the model. The discriminate validity further confirmed that the diagonal values were significantly higher than the off diagonal values (i.e., correlation values) as shown in Table 4. All variables had diagonal elements (AVE) greater than the recommended value of 0.5, and greater than the correlation values; the data demonstrates successful discriminate validation.

Table 3: Scale reliabilities

Variables	AVE	Composite Reliability	Cronbach's Alpha	Redundancy (Q^2)	p-value
Threshold Value	≥0.5	≥0.6	≥0.7 (2 to 3 indicators ≥ 0.4)	≥0.0	≤0.05
Susceptibility	0.700	0.823	0.584	0.003	0.01
Severity	0.680	0.808	0.547	0.002	0.01
Benefit	0.661	0.920	0.893	0.021	0.01
Barrier	0.571	0.841	0.748	0.077	0.01
Cue to Action	0.879	0.781	0.781	0.005	0.01
Self-efficacy	0.709	0.829	0.800	0.060	0.01
Consideration of Future	0.611	0.862	0.811	0.000	0.01
Self-identification	0.802	0.924	0.877	0.000	0.01
Perceived Importance	0.609	0.903	0.872	0.000	0.01
Appearance Concern	0.504	0.857	0.805	0.061	0.01
Likelihood of Behavior	0.572	0.801	0.730	0.000	0.01

Table 4: AVE and latent variables correlation matrix

	APP	BAR	BEN	CFC	CUA	EFF	IMP	LOB	SEI	SEV	SUS
APP	0.504										
BAR	0.049	0.571									
BEN	0.149	-0.088	0.661								
CFC	-0.038	0.325	-0.203	0.611							
CUA	0.308	0.086	0.179	-0.093	0.879						
EFF	0.172	-0.306	0.157	-0.235	0.118	0.709					
IMP	0.364	-0.194	0.311	-0.278	0.238	0.289	0.609				
LOB	0.213	-0.304	0.162	-0.231	0.159	0.322	0.3I8	0.572			
SEI	0.325	-0.310	0.245	-0.303	0.169	0.319	0.316	0.326	0.802		
SEV	0.312	0.145	0.286	0.050	0.310	0.033	0.237	0.105	0.126	0.680	
SUS	0.258	0.126	0.296	0.031	0.297	0.047	0.216	0.123	0.140	-0.093	0.700

APP = Appearance, BAR = Barrier, BEN = Benefit, CFC = Concern of Future Consequences, CUA = Cue to Action, EFF = Self-efficacy, IMP = Importance, LOB = Likelihood of Behavior, SEI = Self-identification, SEV = Severity, SUS = Susceptibility

1.8 Proposed Model

Figure 1 represents the extended HBM proposed by us, Figure 2 represents the primary HBM path model with added variables self-efficacy and cue to action (henceforth referred to as the "intermediate model") and Figure 3 represents the primary HBM path model (henceforth referred to as the "baseline model"). The baseline model consists only of the four primary determinants (*benefit, barrier, susceptibility,* and *severity*) of HBM. In the intermediate model the six variables: *benefit, barrier, susceptibility, severity, self-efficacy* and *cue to action* are the determinants of the healthy eating behavior. In the extended HBM models (Figure 1), *perceived importance, consideration of future consequences, self-identity,* and *appearance concern* were added as an extension to the intermediate model's variables (*benefit, barrier, susceptibility, severity, self-efficacy* and *cue to action).* The variables (*benefit, barrier, susceptibility, severity, self-efficacy, cue to action, perceived importance, consideration of future consequences, self-identity,* and *appearance concern*) serve as independent variables that influence (i.e., are the determinants of) healthy eating behavior in our extended model.

1.8.1   The Influence of the Models' Variables on Healthy Eating Behavior

The structural model determines the relationships between the determinants in the models. Important criteria for evaluating the structural model are the coefficient of determination (R^2) - measures the percentage of variance that is explained by the independent variable of a model, as well as the path coefficients (β) and their corresponding significance level (p-value), which were derived from the t-test (Hair and Ringle, 2011). The structural models and their corresponding are $R^{2,}$ β are as shown in Figures 1, 2 and 3 and summarized in Table 5. The extended HBM model, the intermediate, and the baseline model yield R^2 value of 71, 40, and 20% respectively. The p-values as shown in Table 3 are all ≤ 0.01.

As can be seen from the three figures, numerous interactions exist among the many variables involved in the extended model. However, in designing theory-driven interventions for health promotion and disease prevention designers often need to select from the various variables of HBM since it may not be feasible to implement all the variables in a particular intervention. The practical question, therefore, is which of the variables or which combinations of variable from the HBM will provide the most effective result?

To answer this question, we explored the effect of each variable on healthy behavior by exploring the performance of our model with and without each of the ten variables from our extended HBM. This gives an insight on the proportion of the variance in the dependent variable that is predictable from each independent variable f^2 as shown in Table 6.

We also tested for mediating effect in PLS-SEM and tested for significant mediation using sobel test (Sobel, 1982). The test establishes that the effect *consideration for future consequences, self-efficacy,* and *self-identity on healthy eating behavior are partially mediated* by HBM determinants.

1.8.1.1 The Performance of the Baseline and the Intermediate HBM

The old HBM model comprises of the baseline and the intermediate model.

The structural models of the intermediate and the baseline model are as shown in Figures 2 and 3 respectively and summarized in Table 5. In the baseline model, *perceived barrier* emerged as the strongest determinant of healthy behavior (β = -0.42, p<0.01). It is followed by *susceptibility* with only a weak effect (β = 0.11, p<0.01). The independent variables in the baseline model predicted only 20% of the variance in healthy eating behavior.

In the intermediate model, with the exception of *self-efficacy* and *perceived barrier*, all the HBM variables show only weak association with healthy eating behavior (with β value ranging from 0.02 to 0.08). *Susceptibility* (β = 0.06, p$\leq$ 0.01), *severity* (β = 0.05, p$\leq$ 0.01)*, benefit* (β = 0.02, p$\leq$ 0.01)*,* and *cue to action* (β = 0.08, p$\leq$ 0.01). *Self-efficacy* emerged as the only strong positive and significant determinant of healthy behavior with β = 0.53 and p$\leq$ 0.01. On the other hand, *perceived barrier* remains the only variable that influences healthy behavior negatively with β = -0.20 and p$\leq$ 0.01. The independent variables in the intermediate model accounted for 40% of the variance in healthy eating behavior.

1.8.1.2 Performance of the extended HBM
The new variables (*perceived importance, consideration of future consequences, self-identity, and appearance concern*) added as an extension to the HBM passed both the validity and reliability test. Their test scores exceeded the recommended threshold for all the measured components (see Table 3 and 4). This shows that they are adequate to be used as behavior determinants with the HBM.

The structural model of the new extended HBM is as shown in Figure 1 and summarized in Table 5. All the new added variables to the HBM are positively and significantly associated with healthy behavior with path coefficient (β) value ranging from 0.10 to 0.37. Surprisingly, our model shows that the newly added variables are better predictors of healthy behavior than the variables from the baseline and the intermediate HBM, with the exception of *self-efficacy* (β = 0.39, p$\leq$ 0.01, , f^2 = 21%) - which is part of the intermediate HBM . The contributing effect of each individual variable (effect size) f^2 of the newly added variables ranges from 15% to 20% (see Table 6). *Perceived importance* (β = 0.32, p$\leq$ 0.01, f^2 = 15%), *consideration of future consequences* (β = 0.20, p$\leq$ 0.01, f^2 = 15%), *self-identity* (β = 0.37, p$\leq$ 0.01, f^2 = 20%), and *appearance concern* (β = 0.10, p$\leq$ 0.01, f^2 = 16%). *Perceived Barrier* emerged as the only variable that influences healthy behavior negatively. Again, in addition to the direct impact of the variables on healthy behavior, our model also shows that the primary HBM variables (*susceptibility, severity, benefit,* and *barrier)* mediate the effect of *consideration of future consequences* and *self-identity* on *healthy behavior*.
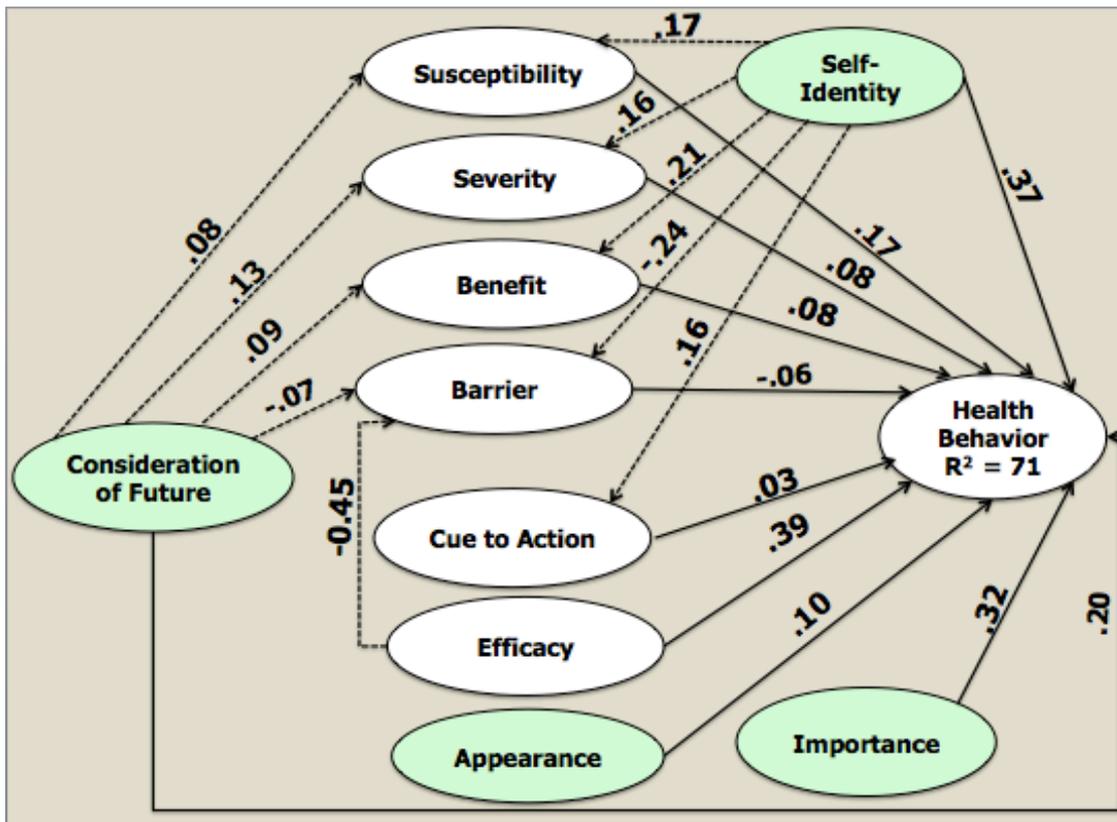
Figure 1. The extended health belief model predicting healthy eating behavior. The ' ' denotes the interactions and the associated no. represents the β values. The ' '
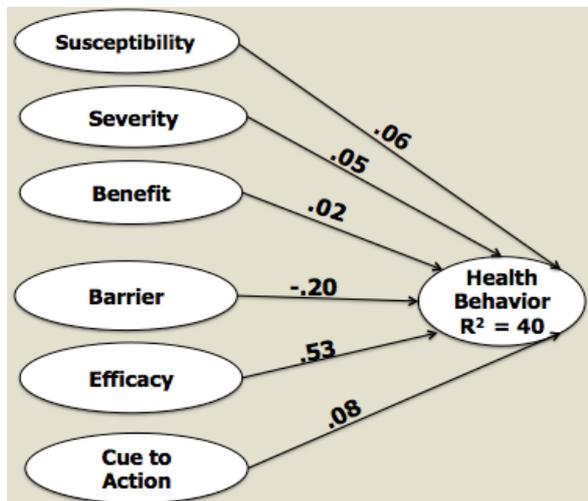

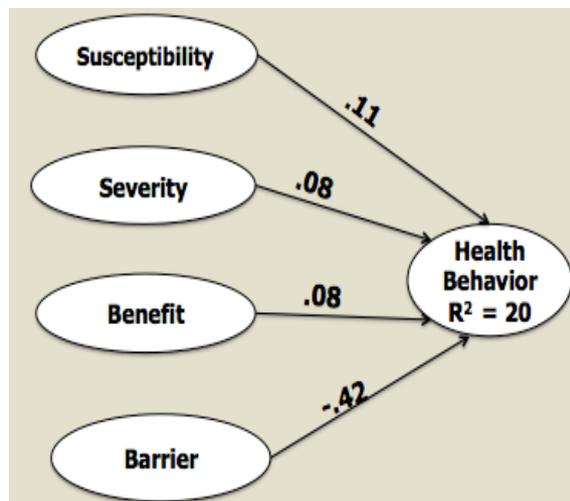**Figure 2.** Intermediate Model Predicting Healthy Eating Behavior

Figure 3. Baseline Model Predicting Healthy Eating Behavior

Table 5: Summary of the Interactions between the determinants and healthy eating behavior

Variables	BEN	BAR	SUS	SEV	CUA	EFF	IMP	APP	SEI	CFC	R²
Extended HBM	0.08	-0.06	0.17	0.08	0.03	0.39	0.32	0.10	0.37	0.20	71%
Old HBM	0.02	-0.20	0.06	0.05	0.08	0.53					40%
Primary HBM	0.08	-0.42	0.11	0.08							20%

BAR = perceived barrier, BEN = perceived benefit, SUS = perceived susceptibility, SEV = perceived severity, IMP = perceived importance, CUA = cue to action, EFF= Self-efficacy, APP = appearance, SEI = self-identity, CFC = consideration of future consequences, R² = coefficient of determination

Table 6: Magnitude of variance on behavior accounted by each independent variable (effect Size)

Variables	Excluded Variable	R²	Change in R² (Effect Size)
LOB ←APP+ CFC+ IMP+ SEI+ EFF+ CUA+ BEN+ BAR+SEV+ SUS	-	0.714	-
LOB ←APP+ CFC+ IMP+ SEI+ EFF+ CUA+ BEN+ BAR+SEV	SUS	0.682	+0.032 (5%)
LOB ←APP+ CFC+ IMP+ SEI+ EFF+ CUA+ BEN+ BAR + SUS	SEV	0.706	+0.008 (1%)
LOB ←APP+ CFC+ IMP+ SEI+ EFF+ CUA+ BEN+ SEV+ SUS	BAR	0.618	-0.004 (6%)
LOB ←APP+ CFC+ IMP+ SEI+ EFF+ CUA + BAR+SEV+ SUS	BEN	0.706	+0.008 (1%)
LOB ←APP+ CFC+ IMP+ SEI+ EFF+ BEN+ BAR+SEV+ SUS	CUA	0.713	+0.001 (0%)
LOB ←APP+ CFC+ IMP+ SEI+ CUA+ BEN+ BAR+SEV+ SUS	EFF	0.564	+0.150 (21%)
LOB ←APP+ CFC+ IMP+ EFF+ CUA+ BEN+ BAR+SEV+ SUS	SEI	0.571	+0.143 (20%)
LOB ←APP+ CFC+ SEI+ EFF+ CUA+ BEN+ BAR+SEV+ SUS	IMP	0.609	+0.105 (15%)
LOB ←APP+ IMP+ SEI+ EFF+ CUA+ BEN+ BAR+SEV+ SUS	CFC	0.610	+0.104 (15%)
LOB ← CFC+ IMP+ SEI+ EFF+ CUA+ BEN+ BAR+SEV+ SUS	APP	0.603	+0.111 (16%)

BAR = perceived barrier, BEN = perceived benefit, SUS = perceived susceptibility, SEV = perceived severity, IMP = perceived importance, CUA = cue to action, EFF= Self-efficacy, APP = appearance, SEI = self-identity, CFC = consideration of future consequences, R² = coefficient of determination

Discussion and Implications

A major limitation of HBM as identified by research and confirmed by our model (see Figure 3) is the low predictive capacity of its primary variables (Abraham and Sheeran, 2005). The HBM variables predict approximately 20% of the variance in healthy behavior on average. This suggests that there are other important determinants of healthy behavior not yet accounted for by HBM. Our work responds to these shortcomings by discovering new variables (*consideration of future consequences, perceived importance, appearance concern, and self-identity* that could extend the capability of HBM. Again, as can be seen from Figures 2 and 3, the majority of research involving HBM assumes the existence of only direct relationships between the variables. This is as a result of lack of clear rule of combination of variables and their relationships. Our model established the existence of both direct and indirect (mediating) relationships among the variables in the HBM.

1.9 The Baseline and Intermediate HBMs

From the SEM results shown in Figures 3, among the four primary variables (*susceptibility, severity, benefit,* and *barrier*) in the baseline model, *barrier* emerged as the strongest predictor of behavior (with path coefficient β = -0.42 and p ≤0.01). This is followed by *susceptibility* (with β = 0.11 and p ≤0.01), finally followed by *severity* and *benefit* with β = 0.08 and p ≤0.01 each as shown in Figure 3. This is in agreement with previous results that have identified *barrier* and *susceptibility* as the best predictor of healthy behavior (Harrison et al., 1992; Janz and Becker, 1984). The baseline model predicted a total of 20% (R^2 = 0.20) of variance in healthy behavior. This is again comparable to earlier research focusing on a variety of health behaviors. The variance explained has ranged from 20% to 40% (Conner and Sparks, 1996; Conner and Armitage, 1998). A sizable amount of variance (approx. 80%) could not be explained by the baseline model.

However, the addition of the two variables *cue to action* and *self-efficacy* in the intermediate model tremendously increased the predictive capability of the model by 100% (from 20% to 40%) as shown in Figure 2. This shows that these two variables account for as much variance as the four primary HBM variables combined. Interestingly, *self-efficacy* emerged as both the strongest and the most significant determinant of healthy behavior with β = 0.53, and p ≤0.01. It is followed by *barrier* with β = -0.20, and p ≤0.01. This shows that health intervention designers should pay more attention to designing interventions that increase the user's feeling of self-efficacy.

1.10   The Extended HBM

To improve the predictive capability of the HBM which is the major limitation of HBM, we added the four variables *consideration of future consequences; self-identity; perceived importance; and appearance*. As shown in Figure 1, including these four variables significantly increased the predictive capacity of the model by approximately 78 % (R^2 increased from 40% to 71%). The statistical finding shows that the four new variables added to the HBM have their place as determinants in HBM model. The model shows that *self-identity, appearance, consideration of future consequences* and *perceived importance* (listed in decreasing order of magnitude of effect) yield substantial improvements (see Table 6). Thus we expect that healthy behavior intervention based on our extended HBM variables will be more effective.

In addition to that, within the extended HBM, *self-efficacy* still emerged as the strongest and most significant determinant of healthy behavior (with β = 0.39, effect size f^2 = 21% and p ≤0.01) (see Figure 1 and Table 6). This again confirms the importance of designing to promote self-efficacy. However, *benefit, severity,* and *cue to action* have weak association with behavior with effect size f^2 = 1%, 1%, and 0% respectively. This shows that *severity, benefit,* and *cue to action* may not be as important as the other variables in promoting the health behavior (e.g., *perceived susceptibility*). This is in line with Bandura (1977 as cited in Munro et al., 2007) "*perceived severity* might have a weak correlation with health action and might even result in avoidance of protective action."

1.10.1 Variables Interactions

Interaction with Cue to Action: Cue to action was introduced by Resenstock (1966) based on the assumption that certain cues would activate/stimulate an individual's perception of threat from certain health condition by influencing the perceived severity, susceptibility, or both. With more powerful cues or accumulation of cues (especially those with more personal relevance), a person is stimulated to take action. Surprisingly, from both our extended model and the intermediate model (see Figures 1 and 2 respectively), it was found that *cue to action* has weak or no effect (with β = 0.03 and 0.08, and p$\leq$ 0.01) on health behavior. As shown in Table 6 *cue to action* has very weak effect (f^2 = 0%) on health behavior. This finding was unexpected. However, we observed that the addition of the four new determinants in our extended model decreased the association between *cue to action* and healthy behavior (i.e., β from 0.08 to 0.03, see Figures 1 and 2). One possible explanation is that the introduction of the variables *self-identity, consideration of future consequences, importance,* and *appearance* reduce the tendency of any form of cues (both external and internal) to trigger behavior performance. Another possible explanation according Baranowski et al. (2003) is that people may not rate the importance of cue to change accurately. Little research has been focused on the impact of cue to action. However, internal cues, such as feeling better physically or mentally after adopting a healthy behavior were rated as the most likely to prompt action (Baranowski, et al., 2003).

Interaction with Perceived Threat: Research on HBM and its applications so far has focused mainly on manipulating an individual's perception of threat (*susceptibility* and *severity*). This is because perceived *susceptibility* and *severity* have been considered as the primary motivation to change for most individuals. Our model, however, shows that perceived *severity* has only a weak relationship with health behavior (with β = 0.08, f^2 = 1%, and p$\leq$ 0.01) and *susceptibility* shows only a moderate association with the behavior (β = 0.17, f^2 = 5%, and p$\leq$ 0.01) as shown in Figure 1 and Table 6. This ordering confirms previous findings that have identified *susceptibility* as a stronger predictor of healthy behavior when compared with *severity* (Harrison et al., 1992; Janz and Becker, 1984) and *severity* as weak predictor that might even lead to avoidance of the health behavior (Bandura, 1977 as cited in Munro et al., 2007). This implies that perceived *severity* may not be as important as perceived *susceptibility* in motivating behavior change. This also implies that health intervention developers focusing on only these key variables (*susceptibility* and *severity*) have only a limited chance of being successful (approximately 6% effect size). It also means that perception of threat alone is not enough to motivate healthy behavior adoption.

Interaction with Perceived Benefit and Barrier: The *perceived benefit* and *barrier* are among the primary variables of the HBM that have been reasonably well researched. The HBM posits that an individual is likely to perform a behavior if s/he perceives that performing the behavior will reduce the negative health outcome (perceived threat). Our data shows that among the four primary variables of HBM (*susceptibility, severity, barrier,* and *benefit*), *barrier* is the strongest and most significant determinant of behavior (with β = -0.42 and p$\leq$ 0.01). However, the addition of *self-efficacy* and *cue to action* in the intermediate modelreduces the inhibiting effect of *barrier* (from β = -0.42 to β = -0.20), as shown in Figure 2. This can be explained by the fact that increasing an individual's feeling of confidence about a particular behavior will reduce the perceived difficulty associated with the performance of that particular behavior and increase the tendency of performing the behavior.

Our model shows that *self-efficacy, self-identity, and consideration for future* are mediated by *perceived barrier* (see Figure 1). Therefore, health intervention designers aiming at reducing the inhibiting effect of *perceived barrier* associated with a particular health behavior should design an application that increases the individual's *self-identity, concern of future, and self-efficacy* about his/her ability to perform a behavior. On the other hand, *benefit*, just like *severity*, has a weak relationship health behavior (with $\beta = 0.08$, $f^2 = 1\%$, and $p < 0.01$). However, it mediates the relationships between *self-identify* and *consideration for future* on behavior (see Figure 1). Similarly, any intervention designed to increase *self-identity* and *consideration for future* will increase the *perceived benefit* associated with a particular health behavior.

Interaction with Self-efficacy: *Self-efficacy* describes an individual's confidence in his/her ability to perform the health behavior. The HBM proposes that an individual is more likely to perform a behavior if s/he believes that s/he is able to perform it. Our extended model shows that among all the ten variables that emerged as determinants of healthy behavior, *self-efficacy* is the strongest and the most significant determinant ($\beta = 0.39$, $f^2 = 21\%$, and $p \leq 0.01$) as shown in Figure 1. Interestingly, *self-efficacy* has both a direct relationship with healthy behavior and an indirect relationship via *barrier* (with $\beta = -0.45$ and $p \leq 0.01$) as shown in Figure 1. This means that self-efficacy not only increases an individual's tendency of adopting a healthy behavior but also reduces the inhibiting effect of *barrier* on behavior performance. The strong and significant negative association of *self-efficacy* with *barrier* ($\beta = -0.45$ and $p \leq 0.01$) means that designing intervention to increase the feeling of *self-efficacy* might be the most effective way to reduce an individual's perceived difficulties associated with a certain behavior. This highlights the need for both health behavior intervention designers and behavioral theorists to pay special attention on self-efficacy and to design their interventions to emphasize self-efficacy.

Interaction with Self-Identity: *Self-identity*, which describes one's perception about him/herself, emerged as the second strongest and significant determinant of healthy behavior (with $\beta = 0.37$, $f^2 = 20\%$, and $p \leq 0.01$), following *self-efficacy*. Among the four new variables that we added to extend the HBM *self-identity* is the best determinant. The strong relationship between *self-identity* and healthy behavior is in line with the Cognitive Dissonance Theory (Festinger, 1957), which suggests that people try to be consistent with their existing views to reduce dissonance. Our results show that people value consistency. Therefore, if an intervention can be designed in a way that associate individuals with certain health behavior and make them commit to a behavior, they are likely to stick to it. Therefore, designers aiming at increasing health behavior can use commitment, consistency, and goal setting to make the user identify with the desired health behavior. Tracking and comparing behavior with stated goals and commitments makes the deviations observable, and will cause dissonance, which could motivate the desired behavior performance.

It is also worth noting that *self-identity* has both direct and indirect relationship with the healthy behavior. *Susceptibility, severity, benefit, barrier,* and *cue to action* mediate the relationship between *self-identity* and healthy behavior (with $\beta = 0.17$, $\beta = 0.16$, $\beta = 0.21$, $\beta = -0.24$, and $\beta = 0.16$ respectively) as shown in Figure 1. This implies that designing to increase *self-efficacy* will invaluably increase the perceived *susceptibility, severity, benefits,* and *cue to action* while reducing the *perceived barrier*

Interaction with Perceived Importance: Perceived Importance describes how much value a person attaches to the outcomes of a particular health behavior. *Perceived importance* is a significant determinant of healthy behavior from our model (with $\beta = 0.32$, $f^2 = 15\%$, and $p \leq$

0.01). This is in line with findings in previous work that stated that *importance* is positively associated with healthy behavior (Deshpande et al., 2009). This positive association of *importance* with healthy behavior shows that the value an individual attached to outcomes associated with a particular behavior is a better determinant of behavior performance than the ability of the behavior to avert perceived threat (benefit). *Perceived importance* is not necessarily associated with threat. However, since several health behaviors (e.g., healthy eating) often have multiple benefits, a prerequisite to designing to increase the perceived importance should be to identify the outcome that is of important to an individual or group of individuals. Designers should, therefore, design personalized interventions that motivate individuals by linking behavior performance to outcomes that are of important to each individual.

Interaction with Consideration of Future Consequences: A major challenge in motivating people to adopt healthy behavior is the invisible immediate and short-term benefit of many health behaviors. Adopting and maintaining a healthy behavior is a difficult task that has almost no immediate health effect. Therefore, *consideration of future consequences measures* the extent to which people consider the potential distant outcomes of their current behavior. Our model shows that *consideration of future consequence* is a significant determinant of healthy behavior (with $\beta = 0.20$, $f^2 = 15\%$, and $p \leq 0.01$). The positive relationship between *consideration of future consequences* and healthy behavior confirms previous study results that consideration for future plays a role in the adoption of healthy behavior (Strathman et al., 1994). Thus, to motivate an individual to adopt a healthy behavior, intervention designers should make the long-term effects of healthy behavior observable.

Another interesting finding from our model is that *consideration of future consequences* has both direct and indirect relationship with healthy eating. The relationship between *consideration of future consequences* and healthy behavior is mediated by *susceptibility, severity, benefit,* and *barrier* (with $\beta = 0.08$, $\beta = 0.13$, $\beta = 0.09$, and $\beta = -0.07$ respectively) as shown in Figure 1. This implies that any intervention that is designed to increase *consideration of future consequences* will also increase the *perceived susceptibility, severity, and benefits* while reducing the *perceived barrier*.

Interaction with Appearance: People may adopt healthy behavior for reasons that are unrelated to health. For instance, concern for appearance has been identified as one of those reasons. From our model, *appearance* is positively associated with healthy behavior ($\beta = 0.10$, $f^2 = 16\%$, and $p \leq 0.01$). This confirms previous research that shows that people are motivated by their concern for appearance and attractiveness (Hayes and Ross, 1987). This is because people believe that attractiveness is linked to life of happiness. Our results also confirm the previous study that shows that weight concern (which can lead to reduced attractiveness) is an important consideration in peoples' decision to adopt a healthy behavior (Orji et al., 2012). Therefore, physical self-presentation is important for motivating healthy behavior change. Designers could emphasize reduced attractiveness as a potential risk of unhealthy behavior.

The Mediating Roles on Consideration of Future Consequences, Self-Identity, and Self-Efficacy: One of the limitations of HBM is the lack of clear rules of combination (Armitage and Conner, 2000). The model did not explicitly spell out the relationships between the variables. A novel contribution of this work is the establishment of the mediating role played by the five HBM's variables (*susceptibility, severity, benefit, barrier,* and *cue to action*) on *consideration of future consequences, self-identity,* and *self-efficacy.* As shown in Figure 1,

the four variables *susceptibility, severity, benefit,* and *barrier* partially mediate the relationship between *consideration for future consequences* and healthy behavior. Introducing *consideration for future consequence* variable will increase an individual's perception about *susceptibility, severity, benefit* and reduces the *perceived barrier* associated with behavior performance. For example, an intervention that increases an individual's consideration of future is more likely to make the individual have a favorable evaluation of the *perceived susceptibility, severity, benefit,* and *barrier* associated with a particular behavior.

Similarly, as shown in Figure 1, along with *perceived susceptibility, severity, benefit, barrier,* and *cue to action* partially mediates the relationship between *self-identity* and healthy behavior. This implies that any intervention that causes one to associate him/herself positively with a certain health behavior (e.g., "I am a healthy eater or health conscious person") will be more likely to increase the likelihood of responding to various cues to action with regards to that particular behavior. For example, an individual who encounters a health message that associates him/her with certain health behavior may be more likely to respond to various cues to action with respect to that particular behavior; see more of the benefits as opposed to the barriers associated with performing the target behavior; and finally have an increased evaluation of perceived threat of the unhealthy behavior. This will lead to an increased adoption of healthy behavior.

Also worth noting is the fact that *barrier* mediates the relationship between *self-efficacy* and healthy behavior. As shown in Figure 1, *self-efficacy* reduces the negative influence of *barrier* on healthy behavior. This implies that designing to increase the feeling of *self-efficacy* using various technological intervention strategies such as role-playing, incremental goal setting, and modeling will reduce the hindering effect of barrier on healthy behavior adoption.

Establishing the existence of mediating relationship contributes to both the theory and the practical application of the theory in intervention design. Theoretically, it provides a holistic understanding of the interaction between the variables (both direct and indirect interactions). In practice, it gives intervention designers an idea of how to combine the variables of the extended HBM to amplify their effect.

Limitations

Although this study enhances our understanding of the factors determining the healthy behavior, there are some limitations that warrant further research.
Most of the survey participants (approximately 60%) in the present evaluation are in the age range of 18-35 years; therefore, care should be taken in generalizing our result for all age groups. A further bias might be caused by the relatively high level of education of the participants – approximately 70% of our participants are at least a bachelor's degree holder. Future work will try to expand the participants group so it is representative of all age groups. Including younger participants would ensure also a wider representation of people with lower education levels (e.g. not yet completed high-school, or middle school), where healthy eating interventions would be particularly important.

The present study tested our proposed model in the healthy eating domain only; there is still the need to validate the extended HBM model in other health behavior domains. In principle, our model could be applied to various health behavior domains (e.g. exercising, smoking cessation, dealing with various addictions). Future studies can also expand this model by adding some other variables that can account for the remaining 29% variance in healthy behavior.

In the future, we would like to conduct a more comprehensive evaluation of the proposed model. We will use the model to develop an application to motivate healthy eating behavior and evaluate its effectiveness.

Conclusion

Behavioral theories play an important role in the design, implementation, and evaluation of health behavior interventions. In recent years, a number of behavior theories have emerged. The HBM is of particular interest, because of its wide adoption and application in several health domains. Several health interventions have been developed that are based solely on the primary variables (*susceptibility, severity, benefit,* and *barrier*) proposed by the HBM. Despite the widespread adoption of HBM, it has failed to provide consistent evidence of success in health behavior promotion. Therefore, it has been argued that the existing HBM's variables are limited in guiding the design of health behavior interventions for two main reasons: (1) the predictive capacity of HBM is low. The primary variables account for less than 21% ($R^2 < 0.21$) of variance in healthy behavior change and the effect sizes of the individual variables are very small. (2) There no is clear rule of combination of the HBM variables. The relationships between the individual variables are not specified. These limitations are the cause (at least to some extent) of the inability of HBM to provide substantial health behavior improvements.

In this paper, we took a first step towards overcoming these limitations. We improved the predictive capability of HBM by extending it to include four other healthy behavior determinants: *self-identity, perceived importance, consideration of future consequences*, and *concern for appearance*. We also explored the interactions between the variables and established some mediated relationships. In the process of ascertaining the suitability of each variable to act as a health determinant within HBM, several theoretical questions were answered and some other findings validated

To show the suitability of our proposed HBM extension, we validated our model in the healthy eating domain. The statistical findings show that the four new variables (*self-identity, perceived importance, consideration of future consequences*, and *concern for appearance*) added to the HBM do in fact all have their place as determinants within the HBM by showing some significant association with healthy behavior. Our newly added variables appeared to be better predictors of healthy behavior than all the previously proposed variables with exception of *self-efficacy* with remains the strongest determinant of healthy behavior. Our extended HBM model led to approximately 78% increase (from 40 to 71%) in predictive capacity from the old model. This shows the suitability of our extended HBM to predict healthy eating behavior and to direct health intervention design.

Finally, to give some insight on the possible combination and relationship between the HBM variables, we systematically explored the model for possible interactions between the variables. The results show that there exist some mediating relationships between some

variables of HBM. The primary HBM variables - *susceptibility, severity, benefit,* and *barrier* do in fact mediate the relationship between *consideration of future* and *self-identity* alongside with *cue to action*. Another novel finding is that *perceived barrier* mediates the relationship between *self-efficacy* and healthy behavior.

This work contributes to both health behavior theory and health intervention design domains. In the theory front, we extended the HBM, validated the extended model and showed that the extended model predicted 71% variance in health behavior, in contrast to the 21% variance predicted by the original HBM. We also compared the old models (the baseline and the intermediate models) with our extended model and showed that our four proposed variables along with *self-efficacy* are better predictors of healthy behavior than all the original variables of the HBM. Our extended HBM significantly increased the predictive capacity. We hope that this new model will spur research on investigating the influence of our proposed variables within other theoretical frameworks (e.g., the TPB).

On the practical side, our discovery of mediating relationships between the extended HBM variables is intended to allow for a more straightforward and informed combination of variables in health intervention design, leading to higher effectiveness of interventions . The mediating effect shows that some variables function as an antecedent to others and, therefore, will produce a better effect when applied together either in succession or simultaneously. For instance, *self-identity* can be applied alongside *susceptibility, severity, benefit,* and *cue to action* to increase their effect. *Barrier* can be significantly reduced following successful implementation of *self-identity* and *self-efficacy*. The increased predictive capacity of our extended HBM also means that interventions designed based on this model have a greater chance of success than those based on the original HBM.

Although most of the variables are important, some variables like *self-efficacy, self-identity,* and *perceived importance* are obviously more important determinants of healthy behavior. Calculating the effect size f^2 (as shown in Table 6) ensures that intervention designers can easily make an informed decision on the choice of variable or a combination of variables to implement in a design.

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