



Developing culturally relevant design guidelines for encouraging healthy eating behavior

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ABSTRACT

Unhealthy eating behavior is a major contributing factor to the onset of several diseases and health conditions (e.g., obesity, type 2 diabetes). It is therefore not surprising that health interventions aimed at modifying dietary behavior have been identified as the cornerstone treatment for many health conditions. Interventions that use persuasive technology can be effective for motivating healthy eating behavior, and recent years have witnessed an increasing number of persuasive technologies with the purpose of promoting healthy eating behavior or attitude by manipulating various determinants of healthy behavior. However, these applications generally take a one-size-fits-all approach that is biased toward individualistic cultures. To resolve this problem, we propose culturally relevant design approaches for tailoring persuasive technology interventions to collectivists and individualistic cultures. Our guidelines are based on a large-scale survey of 554 participants' (collectivist=306 and individualist=247) eating behavior and associated determinants – identified by Health Belief Model – to understand how healthy eating behavior relates to various cultural groups and sub-groups. We developed two models of healthy eating behavior for the collectivist and individualistic cultural groups identified by Hofstede, and an additional eight models to investigate the moderating effect of gender and age on healthy eating behavior. We then explored the similarities and differences between the models and developed persuasive profiles of motivators of healthy eating behavior for each group. Additionally, we proposed two approaches for designing culturally relevant persuasive applications based on our results. The first is a one-size-fits-all approach that will motivate the majority of the population, while not demotivating any user. The second is a personalized approach that will best motivate a particular cultural group. Finally, to make our approaches actionable in persuasive intervention design, we map the theoretical determinants of healthy eating behavior as identified by Health Belief Model to common persuasive system design strategies.

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1. Introduction

Obesity is a major health concern worldwide and is due in large part to individuals taking in more energy through food than is expended through physical activity. Eating behavior is, therefore, an important factor to consider in any intervention targeting obesity. Research has shown that good eating habits can prevent or at least reduce the risk of obesity, heart disease, and diabetes (Wansink, 2006). It is, therefore, not surprising that behavior interventions aimed at modifying dietary behavior have been identified as the cornerstone treatment for these conditions (Lau et al., 2007).

Persuasive technology (PT) aims to bring about desirable change in attitude and behavior without using coercion or deception (Fogg, 2003) and has proven effective at stimulating behavior change in various domains including health (Choi et al., 2005; Khaled et al.,

2006; Ahtinen et al., 2008). A number of PT applications have been developed for promoting healthy eating behaviors (Choi et al., 2005; Ahtinen et al., 2008); however, these applications generally take a one-size-fits-all approach, rather than tailoring the content and strategies to individual users or user groups (Kaptein et al., 2010). For example, although unhealthy eating behaviors and the associated health implications present a global challenge, most of the existing research about PT has been carried out based on cultures from the developed world (e.g., American culture), which are typically individualistic (Khaled et al., 2006). Therefore, existing technologies for promoting healthy eating behaviors might not match the needs of users in collectivist cultures, characteristic of many developing countries.

The realization that the one-size-fits-all approach may not be sufficient to motivate healthy behavior change has led to a growing interest in ways of tailoring interventions to various users and user groups. For example, previous work has shown that a user's personality is an important determinant of motivation and persuadability (Hu and Pu, 2010; Kaptein et al., 2010). Further work showed a relationship between the user's personality and the success of different PT strategies (Halko and Kientz, 2010). Although a few PT systems have been designed with a specific cultural group in mind

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(e.g., Khaled et al., 2006), the influence of various cultural groups – as identified by Hofstede (1996) – on persuasive design and choice of persuasive strategy has largely been ignored. However, research has shown that individualism and collectivism (Hofstede, 1996) greatly influence a user's opinion regarding their ideal body image and belief about the diet–disease connection (Makino et al., 2004). Therefore, it is possible that members of collectivist and individualist cultures will respond differently to various healthy eating determinants, persuasive strategies, and applications, and that persuasive interventions will be more effective when they are culturally appropriate for the population under consideration.

In this paper, we propose culturally relevant design approaches for tailoring PT interventions to collectivist and individualist cultures. Our design guidelines are based on the mixed-methods' study of 554 participants' (collectivist=307 and individualist=247) eating behaviors and associated determinants. The collection of primary survey data was followed by a 10-min interview with 20 randomly selected participants (collectivist=10 and individualist=10). We employed Structural Equation Modeling (SEM) to explore the interaction between the various determinants of healthy eating behavior and to develop the model of healthy eating determinants for each cultural group. We also explored the moderating effects of gender and age group on the model. Our study is based on the determinants (*perceived susceptibility, perceived severity, perceived benefit, perceived barrier, cue to action, and self-efficacy*) identified by the Health Belief Model (HBM) (Rosenstock, 1966), one of the oldest and the most widely employed models of health behavior promotion.

Our models show significant differences between the participants from collectivistic cultures and those from individualistic cultures. The participants from individualistic cultures showed greater perception of susceptibility, severity, barrier, and self-efficacy. With respect to gender differences within each cultural group, collectivist males and females differ in their perception of severity, susceptibility, barrier, and benefit, while individualist males and females differ significantly in their perception of severity and self-efficacy. Similarly, exploring various age groups within each cultural group shows that collectivist younger and older adults differ in their perception of severity, barrier, and self-efficacy while individualist younger and older adults differ in their perception of susceptibility, severity, and cue to action. These differences suggest the need to tailor various PT theories and their associated strategies based on cultural groups (collectivism and individualism). Thus, guidelines for persuasive interventions based on the understanding of the various cultures' health beliefs are needed for effective tailoring of interventions to each cultural group.

To make our findings actionable for designers of persuasive technology interventions, we developed an intervention mapping that linked the determinants to associated intervention design strategies and objectives using the suggestions of Michie et al. (2008). Following our findings that collectivists and individualists show significant differences in the impact of various determinants on their healthy eating behavior, we proposed culturally relevant design approaches for healthy eating interventions.

Our main contributions are as follows: First, we conducted a cross-cultural evaluation of the influence of the determinants identified by HBM on healthy eating behavior and the moderating effect of age and gender, creating 10 unique models for different populations of users. Second, we propose data-driven and culturally relevant (individualist or collectivist) design approaches for developing PT interventions that motivate healthy eating. We also tailor these guidelines to reflect the moderating effects of age and gender and develop personalized persuasive profiles of what motivates different cultural, gender, and age groups. Third, one of the constraints with many theoretical frameworks for intervention development is their abstract nature – there is little

information on how the theoretical constructs can be translated to system design. To make our guidelines actionable in PT intervention design, we compiled and categorized a list of PT strategies and mapped the HBM determinants to appropriate PT intervention design strategies. Finally, we discussed the differences between individualist cultures and collectivist ones from the perspective of PT for healthy eating interventions, based on the results of our mixed-methods' study. To the best of our knowledge, this study is the first to examine the combined effects of culture, gender, and age on healthy eating and to develop culturally relevant guidelines that are immediately actionable for designers and developers of healthy eating intervention technologies.

2. Background

In this section, we present an overview of culture with focus on how it informs behavior. This is followed by a review of human–computer interaction (HCI) in a cultural context and culturally relevant persuasive technology. We conclude by reviewing human food interaction, various motivations for eating, behavior change theories, and persuasive technologies for motivating healthy eating.

2.1. Culture and human behavior

Culture plays an influential role in shaping people's attitudes and behaviors (Khaled et al., 2006). Its effects reflect in almost all areas of human endeavor including the way an individual communicates and interacts with technology. As a result, there is a growing research interest on various ways of developing computer applications to be culturally relevant (Khaled, 2008; Reinecke, 2010; Kimura and Nakajima, 2011). However, there is no universally accepted definition of culture as a concept. One of the earliest definition of culture was given by Sir Edward Tylor who defined culture as a “complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society” (Tylor, 1920). A more recent definition of culture has been given by Hofstede (1997), who conceived culture as “the collective programming of the mind which distinguishes the members of one group or category of people from another”. Finally, in a more general sense, culture has been loosely conceptualized as being based on shared values (Reinecke, 2010). It is acquired and transmitted from one generation to another, and it is shared and practiced by a group of people (Hughes et al., 1993; Kreuter, et al., 2003). Culture informs a group's behaviors, values, norms, and practices and provides rules that govern how to behave (Khaled et al., 2006).

Recent attempts to investigate empirically the differences in cultures based on the value system shared by various groups identified five finite and crucial cultural dimensions (Hofstede, 1996), which include: *collectivism* versus *individualism*, *femininity* versus *masculinity*, *long-term* versus *short-term orientation*, *power-distance*, and *uncertainty avoidance*. At present, much of the cross-cultural research has been focused on the individualism and collectivism dimensions. Research has shown that the individualism and collectivism dimensions account for most of the variance in global differences (Hofstede, 1996; Khaled et al., 2006; Triandis, 1995). Thus, in this paper we rely on these two important and well-researched dimensions: *individualism* and *collectivism* to study cultural differences in healthy eating determinants.

A major distinguishing factor between *individualist* and *collectivist* cultural orientations is the relationship that individuals perceive between one's self and one's in-groups. In an *individualist* culture, there are loose ties between individuals and people are expected to look after themselves and their immediate families at the very most. Compared to people in collectivist cultures, people

Table 1

Summary of the differences between collectivists and individualists (Hofstede, 1996; Ferreira, 2002; Xinyuan, 2005).

Individualist	Collectivist
Motivated by personal achievement	Personal achievement is underplayed in favor of group achievement
Demonstrate image of success through materialism and consumerism	Demonstrate image of success through achievement of social political agendas
Inclined to controversial/argumentative speech and encourage extreme claims	Uses official slogans and subdues hyperbole and controversy
Merit of subject being always analyzed	Mood created by the information being provided
Verbally oriented and very explicit communicators	Visually oriented, most information is implied by the context
Values plain facts. No explicit conclusions	Value explicit statements of benefits, use of emotion, and allows interpretation of facts
Individuals rely on personal experiences	Rely on the experience of trusted others
Emphasize newness, uniqueness, independence, self-improvement, and self-benefits	Emphasize on what is customary (history and tradition) and popular, and on group enjoyment, group integrity, and well-being
Set goals that relate to self-actualization	Set goals for that are related to promoting the welfare of their in-group

in individualist cultures tend to be more independently minded, self-centered, self-oriented, competitive, less cooperative, and less concerned with their in-groups goals, needs, beliefs, norms, and consequences. Individualists are less loyal and less cooperative to the extent that individual interests outweigh group interests. Individualists tend to be self-motivated, goal-oriented, and they use guilt and loss of self-respect as motivators (Hofstede, 1996; Khaled, et al., 2006; Tao, 2005). In addition, individualists exhibit more consistent attitude–behavior patterns than collectivists, are more interested in duties that are of benefits to them self, and consider the individual self as a determinant of his/her self-identity, purpose, and goals (Triandis, 1995; Khaled et al., 2006; Tao, 2005). On the other hand, in *collectivist* society, from birth, people get integrated into strong cohesive groups. The collectivist expects other in-group members to look after them and protect them in exchange for unquestioning loyalty. In a collectivist society, group interest outweighs individual interest, and individuals behave to maintain good and tight relationships within the group to avoid loss of face (Hofstede, 1996; Khaled et al., 2006; Tao, 2005). Moreover, in collectivist cultures, an individual's identity is defined by the in-groups to which the individuals belong; cooperation is high within in-groups. Collectivists are less consistent in their attitude–behavior patterns and work for group benefit (Hofstede, 1996; Khaled et al., 2006; Tao, 2005). The cultural dimensions represent major attempts at understanding deeply ingrained sets of values with the help of a set of tangible variables (Reinecke, 2010). The major differences between collectivist and individualist cultures are summarized in Table 1.

Hofstede's cultural model has been criticized (e.g., see Irani et al., 2010) due to some limitations of the model, such as the broad and binary classifications; however, it is still the most widely referenced cultural model (Bond, 2002; Jones, 2007). For example, several HCI researches have successfully adopted and applied Hofstede's model in their designs (Khaled et al., 2006; Li et al., 2009a,b; Furner and George, 2012). Although we could investigate, develop, and compare our models in the level of country/nationality, we decided to adopt Hofstede's cultural model for the following reasons:

1. Recent research has reproduced and confirmed the validity of Hofstede's cultural models as related to individualism–collectivism. For example, see Schimmack et al. (2005).
2. Hofstede's model has been successfully applied in the design of PT interventions for smoking cessation (Khaled et al., 2006) and sustainable behavior (Kimura and Nakajima, 2011).
3. Individualism and collectivism related cultural factors contributing to the overconsumption of food have been found to be a major contributory factor leading to being overweight and obese (Airhihenbuwa, 2010; Universiteit, 2010).

4. Finally, research has shown that Hofstede's collectivist and individualist dimensions successfully predict healthy eating behavior and response to healthy eating materials (Davis, 2008). This suggests that significant homogeneity exists within the dimensions with respect to eating behavior. Therefore we could develop guidelines for tailoring to these dimensions as opposed to tailoring to individual countries.

2.2. Cultural influence on eating behavior

The success of many interventions aimed at motivating healthy behavior change will be measured by the degree to which cultural and contextual factors are taken into consideration in the intervention design. Health behavior and health belief may be influenced by culture, which is a major determinants of how people understand, interpret, and respond to various experiences (Lim et al., 2009). This is even more evident in obesity interventions because several individual weight management programs have failed to achieve long-term reduction in weight through diet and other interventions targeted at the individual (Airhihenbuwa, 2010). “The contexts that have established and nurtured obesity are systemic and structural, hence the need to turn to culture” (Airhihenbuwa, 2010, p. 3).

Culture influences most aspects of human endeavors including why, what, how, and with whom we eat (Miller and Pumariega, 2001; Airhihenbuwa, 2010). People within a particular community often share common markets, restaurants, and foods. Therefore, over a course of time what, where, how, and when they eat becomes one of the main identifiable characteristics of a community and hence a dependable way of characterizing and possibly distinguishing a community's culture. Once ingrained into a culture, eating behaviors then become a way of expressing cultural identity. For instance, in many collectivist cultures, eating is an important element of social gatherings and it is considered impolite to refuse food especially when presented by a hostess. Similarly, when receiving a guest, it is considered impolite not to offer generous amounts of food (Bureau, 2011). The cultural differences in eating attitudes and behaviors imply that an individual's cultural orientation may influence the attitudes and behaviors around *healthy* eating. For example, research has shown that collectivists–individualists' orientation influences the effectiveness of various healthy eating interventions (Davis, 2008). Therefore, it might be difficult to design an effective intervention for motivating healthy eating without taking the cultural orientation of the target group into consideration.

2.2.1 Motivation for eating

Traditionally, people ate for the purpose of getting the necessary nutrients needed to survive. However, people also eat for

various reasons including emotional eating, eating for health, and eating as a way of forming and maintaining social relationships. Research has shown that in the US, more people consume food with the main intention of satisfying health objectives than in many other nations (Hawks et al., 2003). This cultural orientation is created by media that intentionally alters the perception of food from one of the satisfying nutrients to one of a drug-like medication (health-focus perception). For example, chocolate ice cream is portrayed as a useful drug for relieving negative emotional states (Hawks et al., 2003).

Recent research has shown that people are more motivated to change their unhealthy behavior by their concern for their physical appearance (e.g., concern for weight) more than their concern for diseases (Orji et al., 2012). However, this behavior might differ depending on the cultural background of the participants, including the collectivist–individualist orientation. This claim is supported by the review which shows that the traditional Chinese, Indian, and Arabic cultures prefer plumpness and therefore do not emphasize thinness as a requirement for feminine beauty (Soh et al., 2006). Similar trends have been seen in African Americans where thinness is not a prerequisite for beauty and attractiveness – in fact, certain African Americans still consider being overweight or obese as a sign of good health (Ofosu et al., 1998). A similar study found that most African girls perceive fatness as a sign of happiness and wealth that makes one look respectable while thinness is associated with ill health, particularly HIV, AIDS and tuberculosis (Fogg, 2003). These results suggest that the underlying factors (e.g., concern for weight) and strategies that motivate people to eat healthily or otherwise might differ based on an individual's cultural orientation. In line with this, Hawks et al. (2003) reported a significant difference in motivation for eating between Japanese and US women. Japanese women are more likely to eat in response to physical and environmental cues (motivations) and are less likely to eat in response to emotional states than US women. They found similar trends for Japanese and US men. Participants with US background are prone to emotional eating and at the same time, they feel that losing weight is important (regardless of gender). These findings support the argument that individual differences in motivation for eating are influenced by unique cultural background; however, these differences in motivation are underexplored and largely ignored by many persuasive intervention designers.

2.3. Culture and technology

Recently, there is an increasing amount of research on cultural influences in the design and use of various computing technologies. In this subsection we present a review of culturally relevant computing applications with a major focus in human–computer interaction (HCI) and persuasive technologies (PT).

2.3.1. Human–computer interaction in a cultural context

The increasing integration of computers and computing software into our daily lives has led to grow interest on considering how HCI can help computer applications and devices to provide users with more natural interaction. The effort has led to a universally established design practice in the HCI community that enables designers to develop technologies that are user friendly by leveraging attributes commonly referred to as affordances (Eugene et al., 2009). Developing culturally relevant computer applications is a possible way of adding affordances in a system (Anacleto and Carvalho, 2010). Culture is important in HCI design. According to Bailey et al. (2001), culture should be considered in interactive systems development because it influences the ways that people interact in general. It follows to say that culture will also influence

the way in which people interact with various persuasive applications, their perception of various persuasive approaches, and the influence that persuasive designs have on users' behaviors. Several researchers are beginning to consider the importance of considering cultural issues in computer applications development (for an example see Bailey et al., 2001). Recent research has begun to examine the impact of cultural adaptation of websites and user-interface design on the users. Singh et al. (2006) in their cross-cultural perceptions of various website designs found that users preferred websites that were adapted to their local cultures. Similarly, Xinyuan (2005) analyzed various cultural dimensions and their influence on some aspects of user-interface design. These studies, although diverse in their investigative focus have highlighted the influence of an individual's cultural values and beliefs on their perception, acceptance, and use of computer applications. Persuasive technology is a special class of computing application that can benefit from adapting the persuasive approaches to a user's culture.

2.3.2. Culturally relevant persuasive technology

Research has shown that there is a need to make most computer applications culturally relevant (Khaled et al., 2006; Reinecke, 2010; Kimura and Nakajima, 2011). This need is amplified for computer applications that are designed to motivate healthy behavior change (i.e., persuasive technologies). Persuasive technology (PT) aims to form, alter, or reinforce attitudes and/or behaviors without using deception, coercion, or inducements (Fogg, 2003). The use of PT is often voluntary; therefore, it is necessary for PT to be designed to unobtrusively integrate into user's daily life (Consolvo et al., 2009). Total integration cannot be achieved without taking into consideration various cultural contexts, backgrounds, meaning, and values because culture plays a crucial role in shaping an individual's attitudes and behaviors. According to Grimes and Grinter (2007), cultural relevance is achieved when an intervention design reflects an understanding of the beliefs, norms, needs, and behaviors of the target population. Following from this definition, persuasive technologies (which are often informed by human behavior theories and their associated determinants) can be made culturally relevant by adapting the fundamental theories, determinants, and strategies to the cultural beliefs and norms of the target audience. This does not imply that any persuasive technology interventions that adapt to the cultural dimensions will be successful. Rather, adapting to the cultural dimensions will increase the likelihood that the intervention will be culturally meaningful to the target audience (Grimes and Grinter, 2007) and will thereby increase its effectiveness. Only little research has been done in the area of designing culturally relevant PT. Khaled et al. (2006) examined how cultural differences can influence the effectiveness of various persuasive strategies and claimed that the persuasive strategies currently in use are mostly suitable for individualists and not for collectivists. Following from this, they proposed five collectivist-focused persuasive strategies – *group opinion*, *group surveillance*, *deviation monitoring*, *disapproval conditioning*, and *group customization*. However, these strategies are not based on theories of human behavior change nor on a large-scale study. Similarly, *Smoke?* is a persuasive game for smoking cessation targeted at both collectivist and individualist cultures (Khaled et al., 2009). The design of *Smoke?* was informed by set of collectivist-focused strategies – *harmony*, *group opinion*, *monitoring*, *disestablishing*, and *team performance*. Quantitative evaluation of the two versions of *Smoke?* supports the claim that the culturally matched strategies yield greater persuasion.

Most prior work on matching persuasive strategies to culture focused on smoking behavior. However, strategies that worked in

one domain (e.g., smoking cessation) might not be directly transferable to healthy eating intervention design. This is because eating, unlike many other behaviors with health implications (e.g., smoking) is one of the essentials of life. We all need to eat to get the necessary nutrients needed to survive. This makes it more challenging to design interventions focused on motivating healthy eating and therefore, creates a need for research to examine various health determinants and PT strategies in the healthy eating domain with the aim of developing culturally relevant PT for healthy eating interventions.

2.4. Gender-relevant technology design

Gender differences have also been of interest to researchers from various disciplines for decades. Recently, various computing technology developers are beginning to consider gender differences and its influences in their design decisions (Moss et al., 2006). The gender biases towards specific design elements and their perceived influence is caused by the fundamental differences on how males and females process information, as well as the differences in perceived gender roles in society (Barth, 2012). Some of the work in this area has focused on gender influences in user interface and web design. For example, Moss et al. (2006) reveal differences on how males and females perceive and rate websites. Their studies show that people have the tendency of rating websites higher if they are designed by people of the same gender – males nearly always rate male-designed websites higher than female-designed ones. By default (without any gender neutral or gender specific design guide), male developers tend to design for male esthetics and female developers for female esthetics (Moss et al., 2006). This tendency may also apply to the design of PT. These studies suggest that the different psychology of males and females also reflects in their design inclination and their perception of certain strategies. It therefore follows to say that PT for motivating behavior change can appeal to target gender groups by employing gender-specific design strategies. The choice of strategy and manipulation of the underlying determinants in a persuasive application might differ based on the designer's gender. In fact, a persuasive research has shown some gender differences in perceived credibility (Ferebee, 2008) and social influence, disease concern, and nutrition knowledge (Orji et al., 2013). Similar research has also shown the moderating effect of gender on perceived persuasiveness (Drozd et al., 2012). Therefore, examining the influence of various determinants of healthy behavior for each gender group will be useful in guiding PT designers on the important determinants to focus on when designing gender-tailored or gender-inclusive PT interventions.

2.5. Healthy eating interventions and behavior theories

Persuasive interventions for motivating healthy behavior become more effective when they are informed by various theories of healthy behavior change (Consolvo et al., 2009; Shegog, 2010). In this subsection, we review the theories of health behavior with particular emphasis on the Health Behavior Model. This is immediately followed by a review of various persuasive technologies for motivating healthy eating that have been informed by these theories.

2.5.1. Behavior change theories

Health behavior theories assist in understanding health behavior problems, developing interventions based on salient determinants that affect behaviors, and evaluating the effectiveness of the health interventions. The most effective persuasive interventions for behavior change usually occur when the intervention is

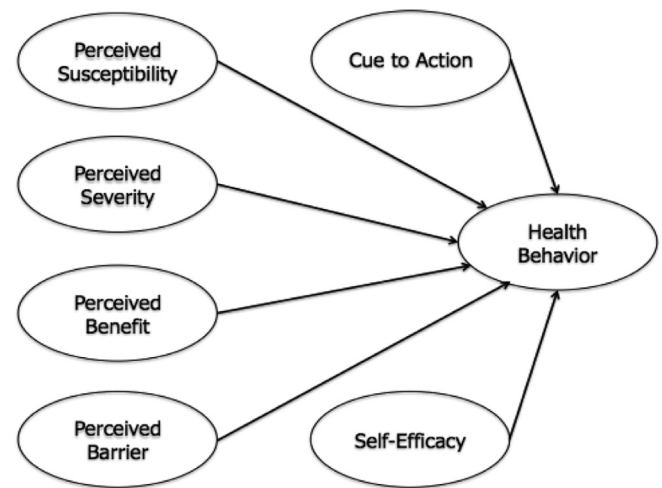


Fig. 1. The Health Belief Model.

behaviorally focused and theory driven (Consolvo et al., 2009). Therefore, PT can be made optimally effective, if they are also informed by these theories (Shegog, 2010). According to Kharrazi and Faiola (2009), using behavioral models to inform interventions for health can increase the usability and the effectiveness of the intervention at achieving the desired outcomes. Several health behavior theories have been used to inform persuasive intervention designs, such as the Theory of Planned Behavior (Ajzen, 1991), the Transtheoretical Model (Prochaska et al., 1992), and the Health Belief Model (Rosenstock, 1966). The most frequently applied health behavior theory is the Health Belief Model (HBM) – Fig. 1. Developed in the 1960s, the HBM investigates why people fail to undertake preventive health measures, and remains one of the most widely employed theories of health behavior (Rosenstock, 1966). 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 behavior change interventions (Glanz et al., 1995). HBM focuses mainly on health motivators; therefore, it is most suitable for addressing problem behaviors that have health consequences (e.g., unhealthy eating and physical inactivity).

HBM is a well-established model that originated in the 1960s, and one may argue that it is outdated and may not be a useful framework for handling recent health challenges such as obesity; however, this is not the case. HBM has been shown to successfully predict healthy eating behavior, weight, and obesity management by several researchers (e.g., see Deshpande et al., 2009; James et al., 2012; Orji et al., 2012a, b; Kim et al., 2012). It has also been adapted and successfully applied in the design of many technological interventions for motivating healthy eating. For example, Winnett et al., (1991) employed HBM to design a computer-based intervention aimed at motivating the purchase of food lower in fat and higher in fiber. The result of the evaluation revealed the efficacy of the intervention at motivating healthy dietary choice. Similarly, Campbell et al. (1994) employed HBM to design a

computer-tailored intervention aimed at increasing the consumption of fruits, juice, and vegetables, and reducing fat intake. Participants received behavioral feedback tailored to their belief about perceived dietary risks, consequences, and self-efficacy expectations with regards to dietary change. Other researchers have used the concepts in HBM, without specifically addressing the model. For example, Grimes et al., (2010) designed a game called *OrderUP!* to help players learn strategies for healthy eating choices. *OrderUP!* manipulated the perceived *susceptibility* and *severity* associated with making unhealthy meal choices by making players lose points for unhealthy choices. The decrease in cumulative points (representing a reduction in health value) portrays how eating unhealthy meals decreases one's general wellbeing and makes one *susceptible* to various health problems. For a review of both implicit and explicit applications of HBM in health intervention design, see (Orji et al., 2013).

2.5.2. Persuasive technology for motivating healthy eating

Recent years have witnessed a continuous increase in research into various ways of using PT to motivate behavior change in healthy eating domains. *Escape from Diab* is an persuasive adventure game on healthy eating and exercise, with the main goal of preventing kids from becoming obese and developing diabetes and other related illnesses (Thompson et al., 2010). *Escape from Diab* employed several strategies to impact players' health belief and motivate behavior change. These included modeling, goal review, and feedback (i.e., increasing *self-efficacy*), problem solving (i.e., impacting skills to overcome *perceived barrier*), and self-monitoring (i.e., impacting *perceived susceptibility*, *severity*, and *cue to action*). *LunchTime* is a persuasive game for motivating healthy eating in young adults (Orji et al., 2012). Players play the role of restaurant visitors, and their goal is to choose the healthiest option from a list of food choices. Players are awarded points based on the relative healthiness of their choice. The point reward can be likened to a *perceived benefit* associated with the healthy choice (choosing a healthy food option). Studies showed that playing the *LunchTime* game increased the players' nutrition knowledge and their general feeling of *self-efficacy* about their ability to initiate and maintain healthy eating behavior. Although successful PT interventions, these examples do not take cultural considerations into account.

An attempt to incorporate culture in persuasive design for healthy eating is *OrderUP!* (Grimes et al., 2010) – a game targeted at an African-American audience. It aims to help players learn strategies for healthy eating choices by having them play the role of a server in an African-American neighborhood restaurant. In contrast to *LunchTime*, *OrderUP!* portrays the perceived threat (*susceptibility* and *severity*) associated with making unhealthy meal choices by making players lose points for unhealthy choices. The decrease in cumulative points (representing a reduction in health value) portrays how eating unhealthy meals decreases one's general wellbeing and makes one *susceptible* to various health problems. Grimes et al. (2008) created a persuasive application called *Eatwell* to recognize the collectivist nature of African American communities. *Eatwell* allows users to record and share their eating routines alongside the success and constrains (i.e., *perceived barrier*) encountered in an effort to eat healthfully in their particular socio-cultural context.

2.6. Summary

This review shows how theoretical determinants informed the designs of PT interventions. However, it is not always obvious which of the determinants and associated persuasive strategies employed made the interventions successful and how the determinants apply

differentially to various cultures. The influence of culture on the various PT designs for healthy eating has largely been ignored. However, healthy eating is one of the domains with deep cultural influence, therefore the need to consider culture in persuasive design for healthy eating is evident (Miller and Pumariega, 2001).

3. Study design and method

In our study, we aimed to address the dearth of theory that can guide culturally relevant PT interventions for healthy eating. We employed a mixed-method study to examine factors affecting participants' healthy eating behaviors. The quantitative component gathered responses to surveys to determine participants' cultural dimension and assign weightings to the six determinants of healthy behavior identified by the HBM. We were specifically interested in determining the influences of the six health determinants (1) *perceived benefit*, (2) *perceived barrier*, (3) *perceived susceptibility*, (4) *perceived severity*, (5) *cue to action*, and (6) *self-efficacy on health behavior* as they apply to decisions around healthy eating behavior. The qualitative part, which involved a 10-min face-to-face interview with 20 randomly selected participants (collectivist=10 and individualist=10) was conducted and recorded by three researchers. The aim of the qualitative study was to confirm participants' cultural background as indicated from the questions in the survey and to clarify responses from the survey. Interview participants were chosen from the list of participants who indicated that they were interested in being contacted for further studies and were available to be interviewed. The participants were asked questions to confirm their cultural orientation (e.g., self-defined identity and group-defined identity, close long-term commitment to in-groups), nationality, general eating behavior, eating with family and relatives, motivation for eating, and barrier to and benefit of healthy eating. In this section, we first describe how we developed the research instrument; this is followed by data collection methods and validation of our analysis approach.

3.1. Measurement instrument

To collect data for our model, we developed an online survey version of the HBM scale and posted announcements in high traffic websites and forums (e.g., schools, churches, and discussion forums) in different countries. The survey was developed after an extensive literature review of behavior change theories, cultural dimensions and human behavior, food human interaction in a cultural context, healthy eating behavior motivators, and persuasive technology interventions for health, and pilot tested ($n=10$) for refinement. The survey instrument consisted of questions on participants' demography and questions of the HBM determinants. The questions used in measuring the six HBM determinants were constructed based on guidelines developed by Abraham and Sheeran (2005) and have been validated on healthy eating by Sapp and Jensen (1998) and Deshpande et al. (2009). All of the HBM variables were measured using participant agreement with a 7-point Likert scale ranging from "1=Strongly disagree" to "7=Strongly agree". These HBM determinant questions included: (1) seven questions measuring perceived benefit (BEN) – e.g., eating healthy diets most of the time would be beneficial to me; (2) seven questions measuring perceived barrier (BAR) – e.g., eating a healthy diet is costly/hard; (3) two questions measuring perceived susceptibility (SUS) – e.g., if I do not eat healthily, I will be at high risk of some dietary-related diseases; (4) two questions measuring perceived severity (SEV) – e.g., the thought of ending up in the hospital due to dietary-related diseases scares me; (5) four questions measuring cue to action (CUA) – e.g., I would

pay more attention to the quality of my food choices if I read information in the mass media (news stories, ads, other programs); (6) three items measuring self-efficacy (EFF) – e.g., I am confident that I could eat healthily within the next two weeks if I want; and (7) five items measuring likelihood of behavior (BEH) – e.g., I intend to make healthy meal choices most of the time in the next two weeks.

To enable us to group participants into their cultural backgrounds, we included a question that asked participants to indicate their nationality based on strong cultural ties. This allowed them to choose nationality based on the culture that reflects in their behaviors. This choice was based on suggestions from the pilot study, where some participants noted that it may be inappropriate to assign a cultural background to them based on their country of origin. To explore the validity of this question for classifying participants into cultural backgrounds, we identified the 20 interview participants' chosen nationalities based on cultural ties from the survey. We then listed some characteristics of both collectivist and individualist cultures (e.g., loyalty and close long-term commitment to family, extended family, and close relationships; independent decision making style; precedence of self over group (family) in major life decision making (e.g., career and choice of life partner)) and asked the interview participants to identify the characteristics that best described them. The cultural background identified by the participants in the interview corresponded to their reported nationality based on cultural ties from the survey. For example, a Nigerian (Nigeria scores 30 on the individualism dimension, and is therefore considered as a collectivist country) residing and studying in Canada identified Canada (Canada scores 80 on the individualist index and is thus considered a highly individualist country) as his nationality based on strong cultural ties. He sees himself as autonomous (self-determined identity) and has no strong and long-term commitment to his family and extended family. In an age where individuals can move to several countries in their life, there will be issues when trying to label a given individual with a cultural association. According to Reinecke (2010), “a person can belong to more than one culture” and an individual's nation is still to date the most frequently used synonym to culture in several cross-cultural studies (Hawks et al., 2003; Khaled et al., 2006; Reinecke, 2010). Thus, to reduce the possibility of an individual having multiple cultural orientations, we excluded participants who indicated nationality based on a cultural tie that is different from their geographical territory of origin. These individuals that cannot be clearly labeled as either collectivist or individualistic are not represented in our sample, and thus represent a limitation of our work. We address this limitation in the discussion.

According to Hofstede (1996), most western societies scored high in the individualist index while non-western societies scored low. Typically, researchers characterize North America, Western Europe, and Australia as individualist societies, whereas Africa, Asia, and South America are described as collectivist societies (Hofstede, 1996; Green, 2005). Therefore, in this paper, we follow a similar classification to assign participants to cultural groups – North America and Western European cultural ties represent the individualistic culture while Africa represents the collectivistic culture in this study.

3.2. Participants

Data for this study were collected over a period of one year (from August 2011 to August 2012). A total of 711 responses were received, of which 554 reported their nationality based on cultural ties from North America, Western Europe or countries in Africa. We chose these nations to be representative of the individualist and collectivist cultures because these nations clearly fall into

Table 2
Summary of participants' demography.

Variables	Collectivist	Individualist	Total (%)
Gender			
Male	170	112	282(51)
Female	137	135	272(49)
Age group			
18–35 (younger adults)	198	186	384(69)
Over 36 (older adults)	81	89	170(31)
Geographical territory			
Africa	307	–	307(55)
North America and Western Europe	–	247	247(45)

either individualist or collectivist cultures based on the individualist index, and because of the large sample that we were able to collect from these nations (as opposed to, for example, countries in South Asia). The only eligibility criterion was that participants were at least 18 years old at the time of data collection. This is in compliance with the study ethics approval and to ensure that the participants were of legal age to make decisions independently (including decisions on what to eat). Table 2 presents the summary of the participants' demographic information. The cultural groups and gender of respondents were well distributed across our population, whereas ages were unevenly distributed.

3.3. Measurement validation

To determine the validity of our survey instrument we performed Principal Component Analysis (PCA) using SPSS 19. Before conducting PCA, the Kaiser–Meyer–Olkin (KMO) sampling adequacies were all > 0.70 and the Bartlett Test of Sphericity was significant at $p < .001$. Thus, the data was suitable to conduct factor analysis (Hinton et al., 2004). Each question loaded onto their corresponding factors and the factor scores (weights) were all > 0.70 .

3.3.1. Confirmatory factor analysis

HBM is comprised of six determinants of healthy behavior – SUS, SEV, BEN, BAR, CUA, and EFF. To verify that our data replicate the six factors in healthy eating behavior, we conducted Confirmatory Factor Analysis (CFA – a statistical procedure that compares the fit of the data with the factor being modeled) using Partial Least Square (PLS) Structural Equation Modeling (SEM). PLS is especially recommended for theory formation and verification (Henseler et al., 2009). Moreover, PLS-Structural Equation Modeling has less stringent requirements concerning data distribution assumptions (Henseler et al., 2009) and can accommodate small sample size compared to covariance-based SEM. In the CFA, the six factors were included as latent (independent) variables, and each was hypothesized to have a direct effect on healthy eating behavior – the dependent variable. Subsequent upon successful validation of the measurement, constructs were included in Structural Equation Model (SEM).

3.3.2. Multi-group comparison

The main objective of our study was to test whether differences exist between collectivists and individualists in terms of their healthy eating determinants, and whether gender and age also moderated the influence of HBM determinants on healthy eating behavior. To examine the differences and similarities between individualists and collectivists (in terms of their healthy eating determinants) we developed 10 different models. In order to test whether differences exist between individualists and collectivists, the sample was split and a model built for each group; we

systematically examined the interactions and the influences of the six determinants (susceptibility, severity, benefit, barrier, cue to action, and self-efficacy) on healthy eating behavior in the two models. Most studies on cross-cultural differences examine only between-cultural variation. However, the validity and generalizability of the findings from the studies might be difficult to claim without examining both the intra-cultural (within the same culture) and inter-cultural (between cultures) variations. According to Green (2005), failure to consider within-cultural variations leads easily to overgeneralization of the findings. Thus, acknowledging intra-cultural variation is essential in cross-cultural comparisons. In this study, we account for both intra-cultural and inter-cultural variations by investigating the moderating effects of gender and age group on individualists and collectivists. The two culture group samples were further split by age and gender to model collectivist males and females, individualist males and females, collectivist younger and older adults, and individualist younger and older adults. Thus, we developed eight additional models of healthy eating behavior; four for the culture/gender groups and four for the culture/age groups (see Table 2).

Prior to comparing our models, we tested for measurement invariance between each pair of samples (collectivists versus individualist, collectivist males versus collectivist females, individualist males versus individualist females, collectivist younger adults versus collectivist older adults, and individualist younger adults versus individualist older adults). This is important because the psychometric properties from each pair of samples must be demonstrated to have the same structure to establish that the groups had similar interpretations of our instrument items. Failure to establish measurement invariance suggests that we have measured different phenomena across the groups, therefore making comparison between groups using our data meaningless (Setterstrom et al., 2012). To assess measurement invariance, we used the component-based CFA in SmartPLS 2 (Ringle et al., 2012) to conduct a factor analysis for each group of data and retained only items that had factor loadings of at least 0.5 in all the groups – while dropping items with factor loadings less than 0.5 from all the groups (Hair et al., 2011). This process established measurement invariance and ensured that our data were suitable for multi-group comparison.

We report here the common set of indices recommended for model validity and reliability in PLS. Reliability was examined using Cronbach's α and composite reliability values. Indicator reliability can be assumed because Cronbach's α and the composite reliability that analyze the strength of each indicator's correlation with their variables are all higher than their threshold value of 0.7 (Chin, 1998). Validity was examined using convergent and discriminate validity values. Convergent and discriminate validity can be assumed as all constructs have an Average Variance Extracted (AVE) (which represents the variance extracted by the variables from its indicator items) above the recommended threshold of 0.5 and greater than the variance shared with other variables (Chin, 1998). Tables 3 and 4 show the scale validity and reliability of individualists and collectivists respectively. The measurement models yielded an acceptable value of all indices for PLS model validity and reliability thereby showing the validity and reliability of the results from our models.

To establish that culture is a reliable characteristic for tailoring PT, we assess significant structural differences between the cultural groups. We used the pairwise comparison approach recommended by (Chin, 2000). Specifically, we used the PLS algorithm in SmartPLS to separately estimate the path coefficient (β) for each group. Then, we used the bootstrap resampling technique to calculate standard error (SE) for each structural path. With the β , SE, and the sample size, we calculated t -statistics and their corresponding p -value used in testing for significant differences

Table 3
Individualist scale validity/reliability.

Variables	AVE	Composite reliability	Cronbach's alpha
Threshold values	≥ 0.5	≥ 0.6	≥ 0.7
SUS	0.769	0.869	0.701
SEV	1.000	1.000	1.000
BAR	0.527	0.850	0.794
BEN	0.558	0.898	0.868
CUA	0.651	0.846	0.775
EFF	0.721	0.836	0.745
BEH	0.665	0.737	0.736

SUS, perceived susceptibility; SEV, perceived severity; BEN, perceived benefit; BAR, perceived barrier; CUA, cue to action; EFF, self-efficacy.

Table 4
Collectivist scale validity/reliability.

Variables	AVE	Composite reliability	Cronbach's alpha
Threshold values	≥ 0.5	≥ 0.6	≥ 0.7
SUS	1.000	1.000	1.000
SEV	0.606	0.741	0.733
BAR	0.560	0.787	0.792
BEN	0.809	0.894	0.764
CUA	1.000	1.000	1.000
EFF	0.572	0.793	0.703
BEH	0.648	0.844	0.725

SUS, perceived susceptibility; SEV, perceived severity; BEN, perceived benefit; BAR, perceived barrier; CUA, cue to action; EFF, self-efficacy.

between path estimates across the cultural, gender, and the age groups. Again, following the pairwise comparison, we controlled for any possible familywise type I error (due to multiple comparisons) using Bonferroni adjustment. We found significant differences across the cultural groups; therefore, we establish that culture is a reliable characteristic for tailoring PT interventions for motivating healthy eating.

To analyze the data from the interview we used observers' examination and key word matching to identify some key themes, which we discuss alongside the quantitative results.

4. Results and interpretation

In this section, we present the results of the 10 structural models and interpret the findings. We further discuss the findings in the general discussion.

4.1. The structural model

The structural models determine the relationship between the determinants (susceptibility, severity, benefit, barrier, cue to action, and self-efficacy) and health behavior. An important criterion to measure the strength of the relationship between variables in structural models is to calculate the level of the path coefficient (β) and the significance of the path coefficient (p) (Hair et al., 2011). Path coefficients measure the influence of a variable on another. The individual path coefficients and their corresponding level of significance obtained from the 10 models are summarized in Tables 5–7.

The results from our models reveals some interesting similarities and differences between participants from individualists and collectivists culture, males and females, and younger and older adults with respect to the influence of the six HBM determinants on their healthy eating behaviors as shown in Tables 5–7. In this section, we first summarize and compare the results for various groups. Finally, we interpret and discuss the influence of various

Table 5

Standardized path coefficients and significance of the models for individualists and collectivists cultures. The numbers represent coefficients that are significant at least at $p < 0.05$ and “–” represents non-significant coefficients.

Factors	SUS	SEV	BAR	BEN	CUA	EFF
Collectivist	–	–	–	0.36	–	–
Individualist	0.11	0.14	–0.22	0.19	–	0.46

SUS, perceived susceptibility; SEV, perceived severity; BEN, perceived benefit; BAR, perceived barrier; CUA, cue to action; EFF, self-efficacy.

Table 6

Standardized path coefficients and significance of the models for the males and females within the individualists and collectivists' cultures. The numbers represent coefficients that are significant at least at $p < 0.05$ and “–” represents non-significant coefficients.

Factors	SUS	SEV	BAR	BEN	CUA	EFF
Collectivist females	0.24	–	–0.15	0.46	–	–
Collectivist males	–	–0.26	–	–	0.15	–
Individualist females	0.19	–0.21	–0.18	0.21	–	0.16
Individualist males	0.13	0.11	–0.27	0.18	–	–

SUS, perceived susceptibility; SEV, perceived severity; BEN, perceived benefit; BAR, perceived barrier; CUA, cue to action; EFF, self-efficacy.

Table 7

Standardized path coefficients and significance of the models for the younger and older adults within the individualists and collectivists' cultures. The numbers represent coefficients that are significant at least at $p < 0.05$ and “–” represents non-significant coefficients.

Factors	SUS	SEV	BAR	BEN	CUA	EFF
Collectivist younger adults	–	0.18	–	0.31	–	0.25
Collectivist older adults	–	–	–0.12	0.25	–	–
Individualist younger adults	–0.14	–	–0.30	0.19	0.14	0.17
Individualist older adults	0.15	–0.13	–0.17	0.25	–	0.19

SUS, perceived susceptibility; SEV, perceived severity; BEN, perceived benefit; BAR, perceived barrier; CUA, cue to action; EFF, self-efficacy.

determinants on the healthy eating behavior of each cultural groups and sub-groups.

4.2. Collectivists versus Individualists

Among the six determinants theorized to influence healthy behavior by HBM, perceived benefit emerged as the only significant motivator of behavior change for collectivists. However, for individualists, perceived severity, cue to action, self-efficacy together with perceived benefit significantly influence healthy eating behavior. Perceived barrier is the only determinant that influences healthy eating behavior negatively. A possible explanation of these results can be found from the characteristics of the collectivists and individualists cultures – individualist culture encourages individual identity and fosters achievements of individual goals, whereas in the collectivist cultures, emphasis is placed on group identities and individuals are encouraged to cooperate in order to achieve group goals (Fjnneman et al., 1996). Healthy (eating) behavior and the associated determinants as highlighted by the HBM emphasize individual actions and perceptions and their effects on individual's health with little or no emphasis on in-groups – the group of people about whose welfare a person is concerned. Therefore, these determinants (with the exception of benefit) might not influence collectivists to adopt healthy eating behavior. This result is related to those of Khaled et al. (2006), who

suggest that various persuasive strategies used to date are mostly suitable for individualists and not for collectivists. Therefore, to make these determinants and their associated strategies effective for collectivists, intervention designers should portray (un)healthy eating with respect to its effects and benefits to an individual's in-group (e.g., family). After all, in collectivist cultures, eating is an important element of every family unit and social gathering (Bureau, 2011). In our post survey interview, 8 of the 10 the participants from collectivists cultures indicated that they eat together with their family members and stick to their family menu most of the time when they do eat with their family. Only 3 out of 10 of our individualist participants indicated eating with their families as opposed to eating what and when they want. This, coupled with the value of in-groups, creates a need for a more collectivist-focused approach for motivating healthy eating.

4.3. Moderating effect age and gender

To explore possible variations and generalizability of our cultural models, we examined the moderating effect of gender and age within the individualist and collectivist cultures. The summary of the models is as shown in Tables 6 and 7. In this section, we discuss the inter-group variations in our models.

4.3.1. The interaction of culture and gender

Several researcher have reported gender differences in healthy eating behavior and motivations for healthy eating (for example, see Dawson et al., 2007; Deshpande et al., 2009; Orji et al., 2013). However, whether there are interactions between gender and culture has not been investigated. As shown in Table 6, gender moderates the influence of the determinants on healthy eating within each cultural group. We present the similarities and differences between males and females (within a culture) with respect to the influence of the determinants on their eating behavior.

4.3.1.1. Collectivist males and females. Collectivist males and females differ significantly in their perceptions of the six determinants. Susceptibility and benefit are the two significant motivators of behavior change for the collectivist female group, whereas for males, cue to action emerged as the single significant motivator of behavior change. On the other hand, barrier influences behavior negatively for females, whereas severity is negatively associated with healthy behavior for the male group. This is in line with a previous study that shows that male students engage in more risky health-related behaviors to show strength, fearlessness, and manliness (Dawson et al., 2007). At the same time, males perceive their health status as excellent because they tend to consider themselves invulnerable to a number of potential health threats (Dawson et al., 2007). This implies that persuasive interventions attempting to motivate healthy behavior by manipulating the potential threats (risk and consequences) of unhealthy eating behavior might not be effective for collectivist males, whereas they are likely to motivate a positive behavior change in collectivist females. Self-efficacy is the only determinant that exerts similar effects on both males and females from collectivist cultures; however, surprisingly, self-efficacy is not significant for both collectivist males and females. This implies that an individual's belief in their own ability is not a significant determinant of healthy eating for collectivists (both males and females) who are more group oriented.

4.3.1.2. Individualist males and females. Individualist males and females share more significant similarities than differences in the influence of the determinants on their healthy eating behavior. The determinants susceptibility, barrier, and benefit significantly influence behavior for individualist males and females (although at different

magnitudes). Susceptibility and benefit are positively associated with healthy eating behavior, whereas barrier influences behavior negatively for both individualist males and females. On the other hand, individualist males and females vary in the influence of severity and self-efficacy. Individualist females perceive severity as negative, whereas severity is positively associated with healthy eating behavior for individualist males (although recall that severity was negatively associated with healthy behavior for collectivist males). Similarly, self-efficacy is perceived as positive by individualist females, whereas it is not significant for individualist males. As both individualist males and females perceive benefit, barrier, and susceptibility as positive, PT designers can manipulate susceptibility and benefit in individualist-targeted PT interventions to motivate healthy eating irrespective of the target gender.

4.3.2. *The interaction of culture and age*

Unlike gender, age differences in healthy eating and belief about healthy eating have only been investigated by few researchers (De Bourdeaudhuij, 1997). However, as shown in Table 7, age also moderates the influence of the determinants on healthy eating. We present the similarities and differences between younger and older adults (within each culture) with respect to the influence of the determinants on their eating behavior.

4.3.2.1. *Collectivist younger and older adults.* The models for younger and older adult collectivists show some interesting similarities and differences. Susceptibility, benefit, and cue to action similarly influence younger and older collectivists' healthy eating behavior. Both younger and older collectivists perceive benefit as positive, whereas susceptibility and cue to action have no significant influence. On the other hand, younger and older collectivists differ in their perception of severity, barrier, and self-efficacy. Younger collectivists perceive severity as positive while severity is not significant for older collectivists. Barrier is not significant for younger collectivists, whereas it negatively influences behavior for older collectivists. Finally, self-efficacy is positively associated with younger collectivists, whereas it is not significant for older collectivists. As benefit is perceived as positive by both younger and older collectivists, PT designers targeting collectivists should employ strategies that emphasize benefits irrespective of the age groups.

4.3.2.2. *Individualist younger and older adults.* Similar to collectivists, the models for younger and older individualists show some interesting similarities and differences. Both younger and older individualists are motivated to adopt healthy eating behavior by benefit and self-efficacy, whereas barrier deters them from adopting healthy behavior. However, younger and older individualists differ in their perception of susceptibility, severity, and cue to action. Susceptibility is positively associated with older individualists, whereas younger individualists perceive susceptibility as negative. On the other hand, older individualists perceive severity as negative while severity is not significantly associated with behavior for younger individualists. Cue to action is positively associated with behavior for younger individualists, whereas it is not significant for older individualists. Similar to the collectivists, these results suggest that the influences of benefit, barrier, and self-efficacy on individualist behavior are similarly perceived by both younger and older individualists. Therefore, PT designers can employ strategies that emphasize benefits and self-efficacy irrespective of the age groups and cultural orientations.

4.4. *The influence of the determinants on health eating behavior*

In this section we discuss the influence of each determinants and offer possible explanations.

4.4.1. *Perceived susceptibility*

The HBM proposes that increasing an individual's perceived risk (susceptibility) associated with a particular health behavior could be an effective way of motivating health behavior change. The results from our models show however that risk perception is only a significant motivator of healthy eating behavior for individualists, collectivist females, individualist females, individualist males, and older individualists and not for collectivists, collectivist males, younger and older collectivists, and younger individualists. The potential risks associated with unhealthy (eating) behaviors is illness and in the extreme case, death. Susceptibility can be seen as a potential loss of a healthy and disease-free life. Therefore, PT designers often portray susceptibility using a loss-framing strategy. The use of loss-framed persuasive appeals has been questioned, and research has therefore examined the effects of potential loss or gain framing on an individual's motivation in cross-cultural context (Han and Jo, 2012). Their results show that collectivists are motivated by gain-framed information, whereas individualists are better motivated by loss-framed appeals. The results from our study support this previous finding, which concluded that individualists care more about what they stand to lose while collectivists care more about what they stand to gain (confirmed by the individualists' and collectivists' interactions with perceived benefit discussed below). This means that an individualist will be motivated to adopt a healthy eating behavior if they perceive that they are at risk of contracting a health condition if they don't perform the behavior. However, knowledge of being exposed to health risk by not performing a behavior might not motivate a collectivist. Surprisingly, the influence of susceptibility on healthy eating behavior is further moderated by age and gender. Collectivist females, individualist females, individualist males, and older individualists are better persuaded by loss-framed appeal. This is in line with previous research that found that females have greater persuasive advantage to loss-framed appeals than males (O'Keefe and Jensen, 2009).

Again, the varying influence of susceptibility also suggests that there may be some differences between collectivists and individualists, males and females, and older and younger adults in their belief about diet-disease relationships. Collectivists in general, may not view disease as something that is caused or can be prevented through healthy eating. For example, research has shown that attributional style (a casual explanation process used in understanding the causes of an action or event) differs across cultures. People from diverse cultural backgrounds often make different attributions of illness (its causes, cures, treatment, and symptoms) and health (Vaughn et al., 2009), which in turn affects their health beliefs. For instance, with regard to health belief, African Americans (generally considered collectivists) are more likely to attribute illness to external sources that are beyond their controls (e.g., destiny or the will of God) and to believe in the healing power of prayers (Klonoff and Landrine, 1996). On the other hand, the Anglo Americans (more individualistic oriented) hold more traditional Western health beliefs that individuals are responsible for their health and that illness can be treated without reference to family, community, or deities (Landrine and Klonoff, 1992).

Therefore, motivating healthy eating by manipulating potential risks might not be a likely motivator of behavior change for the collectivists (specifically the males, and both older, and younger collectivists) who attribute illness or possible cures to external sources. The situation is similar for young individualists who perceive susceptibility as negative and may be demotivated from adopting healthy behavior by any intervention employing susceptibility. Our results also suggest that younger adults do not consider the relationship between their dietary behavior and diseases. This is in line with a previous study that suggests that young adults tend to care more about peripheral need (e.g., physical appearance) and thus, care less about

potential risk of unhealthy behavior (e.g., diseases) (Orji et al., 2012). This implies that persuasive interventions attempting to motivate healthy behavior by manipulating the risk associated with unhealthy eating (as seen in many PT for healthy eating today, e.g., Grimes et al., 2010) might not be effective for younger adults (collectivists and individualists) and collectivists (males and older adults), whereas they are likely to motivate a positive change in behavior for females of both collectivist and individualist cultures, and individualists (specifically older adults, males, females).

4.4.2 Perceived severity

The HBM theorizes that the perceived seriousness (severity) of the consequences of developing a health condition positively influences an individual's behavior. From the results of our models, similar to susceptibility, severity is a significant positive motivator of health behavior for individualists, individualist males, and younger collectivists. On the other hand, severity is negatively associated with healthy eating behavior for collectivist males, individualist females, and individualist older adults and does not have significant influence on the other groups (collectivists, collectivist males, older collectivists, and younger individualists). This closely follows from the explanation given above about susceptibility. People who attribute the causes and cures for disease to external factors will have unfavorable beliefs about the relationship between diet and disease. They are more likely to underestimate the consequences associated with a particular health condition and the contributory effects of unhealthy diets to such health conditions. Beliefs about the diet-disease relationship have significant effects on health belief and health behavior (for example, see Smith et al., 2000). The non-significant association of severity with healthy eating behavior for collectivists, collectivist males, and older collectivists, and young individualists is in line with previous research that found severity to be a weak predictor of health behavior (Janz and Becker, 1984). Similarly, the negative association of severity with healthy eating behavior for collectivist males, individualist females, and old individualists is in line with Bandura (1997), who warns that the use of threat (susceptibility and severity) as motivators might be counterproductive. This is probably because increasing the magnitude of the perceived consequences associated with unhealthy behavior might make it appear unreal and uncontrollable to many groups. Excessive use of threat might make people doubt their abilities to control the health threats and therefore make them avoid the associated health behavior (Bandura, 1997) or even adopt the unhealthy option. Therefore, severity should be applied in PT intervention design with caution. The mixed influence of severity and susceptibility on healthy eating behavior for various groups stresses the need to tailor PT applications based on an individual's perception of threat.

According to our interviews, both individualists and collectivist believe in the diet-disease relationship in general; however, the *most important benefit* of healthy eating identified by our individualist participants is the efficacy of healthy eating to keep them from diet-related health problems. This difference between collectivists and individualists with respect to the most important benefit probably explains why susceptibility and severity are significant determinants for individualists but not for collectivists who believe that the most important benefit of healthy eating is not health (and disease prevention) but getting the needed energy for conducting daily activities.

4.4.3 Perceived barrier

As expected, barrier is the only determinant that is not perceived as positive by any group; in fact, it significantly influences healthy eating behavior negatively for most of the groups. However, barrier is another distinguishing determinant between collectivists and individualists. Barrier negatively influences the

individualists, whereas the collectivists do not show significant reaction to perceived barrier but are significantly motivated by perceived benefit (as shown in Table 5). This is probably because individualists emphasize personal achievement and self-benefit and are therefore more sensitive to barrier as opposed to collectivists that place emphasis on groups (Hofstede, 1996; Ferreira, 2002; Xinyuan, 2005), thereby undermining the negative influence of barrier. Therefore, creating a successful healthy eating intervention targeting collectivists will likely require designers to emphasize the perceived benefit more than lowering the cost (barrier) of adopting the healthy behavior. People usually weigh the benefit and cost to decide on their course of action. Our results show that barrier is moderated by age and gender; barrier is not significantly associated with healthy eating behavior for collectivists (males and younger adults), whereas it deters behavior for all the other groups. Healthy eating intervention designers should therefore plan to deal with the inhibiting effect of barrier in their design.

From our interviews, we found that both collectivists and individualists believe that healthy eating is difficult. For individualists, time pressure, taste factor, and lack of motivation emerged as the most frequently identified barrier to healthy eating, whereas for collectivists, cost, availability, and social pressure are the barriers. That social pressure is identified as a major barrier to healthy eating is in line with one of the characteristics of collectivists – commitment to in-group.

4.4.4 Perceived benefit

Surprisingly, benefit is the only determinant that has significant influence on healthy eating behavior for all the groups except for collectivist males, for whom it is non-significant. For collectivists and collectivist older adults, benefit emerged as the only determinant that significantly motivates healthy eating behavior, as opposed to barrier, which had no significant influence on collectivists. This confirms that collectivists care more about what they stand to gain as opposed to the cost. With respect to the individualists, both barrier and benefit are significant and they exert opposite effects. This suggests a need for healthy eating interventions to be designed to balance the benefit–cost ratio associated with performing healthy behavior. Individualists are more likely to perform a behavior when the expected benefit outweighs the cost. One of the characteristics of individualists is that they value plain facts (Hofstede, 1996; Ferreira, 2002; Xinyuan, 2005). Therefore, providing facts about the cost-benefit ratio of healthy eating behavior, and placing them side by side in a PT intervention will likely motivate individualists more than drawing explicit conclusions based on benefits alone. On the other hand, explicit statements of benefits (with or without much emphasis on barrier) will likely motivate collectivists more. Regarding the gender groups, similar to the general collectivists, young collectivists care most about what they stand to benefit as opposed to barriers, which does not have a significant influence. Therefore designers targeting young collectivists should make obvious the perceived benefit more than lowering the cost. The various female groups as well as the older adults groups are significantly influenced by both barrier and benefit and they exert opposite effects. This suggests that the groups may use a rational approach to weigh the benefit-cost ratio to decide whether they should adopt a healthier eating behavior.

As stated in our discussion of severity, both collectivists and individualists think that there is a relationship between what they eat and their health. The three main benefits of healthy eating identified by our interview participants were reduced risk of diet-related health problems, improved physical attractiveness, and getting the needed nutrients for daily activities. Maintaining good

health is the most important perceived benefit of healthy eating for individualists while for the collectivists, getting the adequate amount of nutrients needed for daily activities is the most important. Although the specific benefits differ by cultural group, the use of benefits as a strategy is motivating for both groups. Therefore, intervention designers should employ strategies that emphasize the various benefits of healthy eating for both collectivists and individualists.

4.4.5 Cue to action

Cue to action – which can be thought of as any event or stimulus that triggers the performance of a target behavior – is not significant for most of the groups, except for collectivists males and young individualists. This result is surprising considering the extensive use of various cues to action (e.g., prompts, reminders, alerts, biofeedback) in interventions that motivate healthy behavior. Although the result is unexpected, it supports some other findings that concluded that cue to action did not aid the adoption of healthy behavior (Michie et al., 2008). A possible explanation according to Baranowski et al. (2003) is that people may not rate the importance of cue to change accurately. However, from our post survey, internal cues such as feeling better physically or mentally after adopting a healthy behavior were rated as the most likely to prompt action.

As previously mentioned, collectivists reported in the interview that they were more likely to stick to their family menu and eat together with family. This suggests that collectivists are more likely to respond to external cues to action (e.g., family members reminding them to eat healthily). Therefore, social influence may be an important variable to consider when designing for collectivists. Thus, there is a need for future study to investigate the effect of social influence on both collectivists and individualists. On the other hand, individualists who believe that good health is the most important benefit of healthy eating may be motivated to change by internal cues to action – for example, change in health condition that can be associated with (un)healthy eating.

4.4.6 Self-efficacy

Self-efficacy, which describes an individual's confidence in his/her ability to perform the health behavior, emerged as the strongest positive and significant determinant of healthy eating for individualists, as expected. This follows closely from the characteristics of individualists who tend to be more inclined to personal attributes (e.g., ability, achievements, willpower, and opinion) and are therefore self-reliant (Fjerner et al., 1996; Hofstede, 1996; Ferreira, 2002; Xinyuan, 2005). Our results support this idea; individualist females, individualist younger adults, and individualist older adults are significantly and positively influenced by self-efficacy (as are young collectivists). The belief in their capability to adopt and maintain healthy eating is the most important determinant that motivates an individualist to adopt healthy eating behavior. This is also in line with Oettingen (1995) and Earley et al. (1999), who suggest that members of individualist cultures feel more self-efficacious with personal feedback, rather than group-based feedback. This is not particularly true for collectivists, who are more group oriented – sometimes to such an extent that it undermines personal capabilities. Therefore, healthy eating behavior might not necessarily be influenced by a collectivist's belief in their ability to enact the behavior. Our results support this; as shown in Tables 5–7, self-efficacy is not a significant motivator of healthy eating for collectivists, collectivist males and females, and older collectivists. Self-efficacy is also not a motivator for individualist males; however, it does not demotivate any of these groups. Similar to benefit, self-efficacy is another determinant that is not perceived as negative by any group. This implies that designing to increase an individual's confidence in his/her ability to perform the health behavior will motivate a

Table 8

Summary of persuasive profile for motivating healthy eating behavior for various cultural sub-groups. These determinants will significantly motivate majority of people in the group without demotivating any.

Cultural Sub-groups	SUS	SEV	BAR	BEN	CUA	EFF
Individualist	✓	✓		✓		✓
Collectivist				✓		
Collectivist females	✓			✓		
Collectivist males					✓	
Individualist females	✓			✓		✓
Individualist males	✓	✓		✓		
Collectivist younger adults		✓		✓		✓
Collectivist older adults				✓		
Individualist younger adults				✓	✓	✓
Individualist older adults	✓			✓		✓
Collectivist and individualist males	✓			✓	✓	
Collectivist and individualist females	✓			✓		✓
Collectivist and individualist younger adults		✓		✓	✓	✓
Collectivist and individualist older adults	✓			✓		✓

SUS, perceived susceptibility; SEV, perceived severity; BEN, perceived benefit; BAR, perceived barrier; CUA, cue to action; EFF, self-efficacy.

positive behavior change for many people while not harming others. Therefore, PT designers should use various mechanisms (e.g., graded task, incremental goal setting, rehearsal) to promote self-efficacy in their design.

4.5. Summary

Although many PT designers adopt a one-size-fits-all approach, there might sometimes be a need to design PT interventions that target a particular subgroup (e.g., collectivist females, individualistic young people). The results from our models also provide insights into the determinants that could be reinforced to motivate behavior change in various sub-groups. Table 8 presents a summary of persuasive profiles – a list of determinants that could be reinforced to effect a positive change in behavior for various cultural subgroups. The listed determinants motivate a positive change in behavior for various groups without demotivating any.

5. General discussion

In this section, we first describe approaches for applying the results from our models in the design of PT for motivating healthy eating behavior. Finally, we describe the limitations of our study and opportunities for future work.

5.1. Culturally relevant design approach

In this section, first, we present a mapping of the theoretical determinants to persuasive strategies that are more actionable in PT interventions design. Second, we present two approaches for applying our models' results to PT intervention design. Finally, we conclude by highlighting the limitations of our work and opportunities for future work.

5.1.1 Persuasive system development Strategies and HBM

Over the course of the years, several persuasive strategies have been developed. Based on the extensive literature review, we identified and compiled a number of persuasive strategies that could be applied in the design of PT for motivating healthy eating. There is no definitive list of PT strategies, therefore, we performed an affinity mapping exercise on existing lists of persuasive strategies (e.g., Fogg, 2003; Michie et al., 2008; Oinas-Kukkonen and Harjuma, 2008) and categorized them based on four categories proposed by Oinas-Kukkonen and Harjuma (2008), as shown in

Table 9. We identify ways in which HBM can be integrated into PT for healthy eating by mapping the six HBM determinants (susceptibility, severity, barrier, benefit, cue to action, and self-efficacy) to the identified actionable PT design strategies (as shown in Table 10). Three experts reviewed the definition and applications of various persuasive strategies and HBM determinants in intervention design, and together mapped them to the selected candidate persuasive strategies from Table 9 that could be used in representing the six health determinants. For example, we mapped the determinant self-efficacy with role-playing, graded task, praise, and recognition strategies. Strategies such as praise and recognition (for any attempt towards performing the desired health behavior) promote one's positive feeling with respect to the health behavior. This in turn boosts one's confidence about his/her ability to perform the behavior – self-efficacy. Role-playing and graded task from the primary task support category can build self-efficacy in relation to the particular task.

5.1.2 A “one size fits all” PT intervention design approach

Tailoring persuasive systems for motivating healthy eating to various users and user group is advocated by PT researchers because of its track record of success; however, there are times that designing for broadest possible audience is desirable (e.g., for economic reasons). In this section, we describe how our findings can be applied in designing PT for motivating healthy eating for a broad audience, to appeal to the majority of the target users without demotivating any.

Our results show that perceived benefit influences healthy eating behavior positively for all the groups – collectivists (females, younger, and older adults), individualists (males, females, younger adults, and older adults) – and does not negatively impact any group. Therefore, PT designers aiming to appeal to a broad group of users should employ persuasive strategies that emphasize benefits of healthy eating behavior. For example, the strategies of reward/positive reinforcement and gain-framed appeal in the dialog support strategy category emphasize benefits, while the credibility support strategies of group endorsement and expert endorsement reinforce the benefits of the healthy eating behavior (see Table 10).

The determinant self-efficacy significantly impacts individualists, individualist females, younger collectivists, and older individualists positively and does not negatively impact other groups. Increasing an individual's feeling of self-efficacy will motivate the adoption of healthy eating behavior for the majority of the users while demotivating none. Thus, PT designers aiming to appeal to a broad audience should include persuasive strategies that address self-efficacy. For example, role-playing, graded task, and incremental goal setting in the primary task category and praise and recognition in the dialog support and social support categories respectively will build self-efficacy around healthy eating behavior within the context of PT interventions.

Our results also showed that perceived barrier does not motivate any group. It significantly impacts most user groups negatively. Therefore, PT designers should avoid PT strategies that allude to barriers to the adoption of healthy behavior. Some persuasive strategies like punishment, negative reinforcement, and extinction from the dialog support strategy category relate to barrier and may not be effective for any user group and therefore should be avoided or applied with caution. This is in line with recent work showing how negative reinforcements might not be as effective for behavior change as positive reinforcements (Daniels, 2003). As opposed to employing strategies that suggest barriers to healthy eating, PT designers should employ strategies that equip players with skills to overcome barrier (e.g., problem solving).

5.1.3 Personalized PT design approach

Although designing for the broad audience could be desirable from the economic point of view, in certain situations, personalizing persuasive experience for a particular user or user group might be appropriate.

For example, consider the task of developing PT for motivating healthy eating behavior for Ghanaian males. Ghana, with a low score of 15 in individualistic index is considered a highly collectivistic society, according to Hofstede (The Hofstede Center). Cue to action is the only determinant that positively incentivizes collectivist males. Therefore, PT strategies related to cue to action should be emphasized in designing PT to motivate behavior change in collectivist males. Thus, strategies such as reminder and suggestion would work well in this context. However, PT strategies related to severity should be avoided for collectivist males because severity is negatively associated with healthy eating behavior for this group. Hence, PT strategies such as systematic desensitization and vicarious reinforcement should be avoided.

Consider also a designer tasked with designing PT for motivating healthy eating behavior in younger adults (from both collectivist and individualist cultures). Although strategies relating to benefit, cue to action, and self-efficacy can be applied to develop PT targeting younger adults from both collectivist and individualist background, younger adults are among the few groups that are positively incentivized by severity. Therefore, PT personalized for younger adults can effectively use strategies that promote severity alongside strategies promoting benefit, cue to action, and self-efficacy, as listed in Table 10. For example, systemic desensitization, vicarious reinforcement, cognitive restructuring, and biofeedback (from the primary task category) could work well for younger adults. On the other hand, if the targeted group is older adults (from both collectivist and individualist backgrounds), alongside strategies relating to benefit and self-efficacy, the PT intervention should emphasize susceptibility for interventions targeting older adults. Specifically, strategies such as self-monitoring, loss-framed appeal, monitoring, and simulation, which all relate to susceptibility, could be applied in this context for increased persuasive appeal.

Again, consider a designer charged with developing PT to promote healthy eating behavior for Canadians. Canada is highly individualistic country and scores 80 in individualistic index (Hofstede, 1996). Although, according to our result, persuasive strategies that are related to perceived benefit (e.g., reward, gain-framed appeal), severity (e.g., biofeedback, vicarious reinforcement, and systemic desensitization) and susceptibility can be employed as shown in Table 8, individualists is also the group that is most positively incentivized by self-efficacy, as shown in Table 5. Thus, PT personalized for individualists should employ strategies that relate to self-efficacy for an increased persuasive appeal. Strategies such as role-playing, graded task, incremental goal setting, and modeling could be employed in this context (as shown in Table 10) to build self-efficacy. On the other hand, if the target population is collectivists, it is necessary to employ strategies that emphasize and promote benefit when designing PTs targeted at collectivists. As opposed to individualists, collectivists are positively incentivized by benefit only. Thus, persuasive strategies such as reward, gain-framed appeal, and group contingency in the dialog support category can give users an idea of the benefits associated with healthy eating behavior, while group endorsement and expert endorsement in the credibility support category impact and strengthen belief about the associated benefit of healthy eating behavior.

Lastly, consider a designer tasked with building a persuasive casual game – “games that generally involve less complicated game controls and overall complexity in terms of gameplay or investment required to get through game (Wallace and Robbins, 2006)” – for motivating healthy eating behavior. Casual games

Table 9
Persuasive strategies organized by category. These strategies are drawn from multiple sources and are not a definitive list (Fogg, 2003; Michie et al., 2008; Oinas-Kukkonen and Harjumaa, 2008).

Category	Persuasive strategy	Strategy explanation
Primary task support strategies	Monitoring	Allow one party to monitor behavior of another party
	Self-monitoring	Allow people to monitor themselves to inform them about how they might modify their attitudes or behaviors to achieve a desired goal or outcome
	Reduction	Reduce effort required to perform a behavior and make it easier to perform
	Tunneling	Lead users through predefined steps for accomplishing the target behavior and guide them from distracting actions
	Feedback	Provide information about an individual's performance
	Personalization	Offer personalized contents and services to users. Contents are tailored based on a user's need
	Customization	Provide user an opportunity to adapt contents to their needs or choices
	Biofeedback	Provide means for user to observe changes in body system in response to their behavior
	Graded task	Allow user to start with easy tasks and make them increasingly difficult until target behavior performed
	Incremental goal setting	Provide users opportunity to start with an easy goal and increase gradually
	Goal setting	Allow users to set behavioral goal
	Experiential	Presents tasks for users to gain experiences to change motivation
	Role-playing	Allow users to perform behavior in simulated situation
	Simulation	Provides means for a user to observe the cause-and-effect linkage of their behavior
	Self-modeling	Allow user to observe his/her behavior in simulated environment
	Cognitive restructuring	Changes user's cognitions about causes and consequences of behavior
Systematic desensitization	Graded exposure of user to increasingly threatening experiences	
Rehearsal of relevant skill	Provide an opportunity for a person to perform target behavior repeatedly in a safe environment	
Dialog support strategies	Reward/positive reinforcement	Offers virtual rewards to users for performing the target behavior
	Negative reinforcement	Contingent removal of aversive consequence, i.e., if and only if behavior is performed
	Punishment	Contingent aversive consequence, i.e., if and only if behavior is not performed
	Praise	Applaud users for performing the target behavior via words, images, symbols, or sounds
	Reminder	Remind users of their target behavior
	Gain-framed communication	Portray behavior outcome in the form of what user stands to gain
	Loss-framed communication	Portray behavior outcome in the form of what user stands to lose
	Prompt	Stimulus that elicits behavior through prompting
	Persuasive communication	Credible source presents arguments in favor of the behavior
	Extinction	The removal of a reinforcement, e.g., reward
	Group contingency	The contingent relationship between the completion of a given task or specified behavior and access to a specific reward
Credibility support strategies	Suggestion	Suggest certain behaviors (for achieving favorable outcome) to the users during the system use
	Group endorsement	Provide endorsements from affiliated groups
	Expert endorsement	Provide endorsements from respected source
	Self-appraisal	Allow individuals to appraise his/her own performance
	Group appraisal	Allow individual's performance to be evaluated by his/her group members
Social support strategies	Social role	Social encouragement, feedback, etc.
	Social comparison	Provide means for one to view and compare his/her performance with the performance of other users
	Social competition	Provide means for a user to compete with others
	Social facilitation	Provide means for discerning other users who are performing the behavior
	Cooperation	Requires users to cooperate (work together) to achieve a shared objective
	Normative influence	Provide means for gathering together people who have the same goal and get them to feel normed
	Modeling/demonstration	Provide opportunity for user to observe the behavior of others
	Vicarious reinforcement	Provide opportunity for user to observe the consequences of others' behavior
Recognition	Provide public recognition for users who perform their target behavior	

Table 10
Sample mapping of determinants to persuasive strategies.

Self-efficacy	Perceived benefit	Perceived susceptibility	Perceived severity	Perceived barrier	Cue to action
Role-playing	Reward/positive reinforcement	Self-monitoring	Systemic desensitization	Negative reinforcement	Reminder
Graded task	Gain-framed appeal	Simulation	Vicarious reinforcement	Punishment	Suggestion
Incremental goal setting	Group contingency	Monitoring	Biofeedback	Extinction	Biofeedback
Modeling	Group endorsement	Loss-framed appeal	Cognitive restructuring		
Recognition	Expert endorsement				
Praise					

have great appeal for females and the older adult demography (Sullivan, 2009), and there are several persuasive casual games aimed at motivating healthy eating (for example, see Grimes et al.,

2010; Orji et al., 2012). Although persuasive strategies relating to benefit and self-efficacy (as already discussed) could be applied to these two groups, older adults and females are both positively

incentivized by susceptibility, as shown in Table 8. Because we can assume that a large proportion of the casual game players will fall into one of these two groups (older adults and females), it is appropriate to use strategies related to susceptibility when designing persuasive casual games. Thus, strategies such as self-monitoring, loss-framed appeal, monitoring, and simulation could be applied in this context as they relate to susceptibility.

To summarize, these examples demonstrate how we can personalize to various groups and sub-groups. This is accomplished using the results from our models and affinity mapping exercise as shown in Tables 9 and 10. Personalizing PT design to a specific group and sub-group is accomplished using Table 8. These scenarios illustrate how our results could be applied to tailor PT for motivating healthy eating to various groups. However, it is not exhaustive; there are numerous ways that PT applications for motivating healthy eating could be tailored based on our results. Moreover, the results from our models could also be used to guide the evaluation of PT for motivating healthy eating behavior. For example, if a PT aims to evaluate the effect of perceived benefit in motivating healthy behavior, it might be necessary to eliminate all other persuasive strategies that do not affect perceived benefit. The mapping of health determinants to PT strategies will be useful in deciding on the PT components to include and evaluate. Additionally, with the help of our models, PT intervention designers can easily evaluate and interpret the effectiveness of their applications with respect to the underlying theoretical determinants being manipulated. Our results clearly have wider applicability. They can be used to develop and evaluate interventions without an explicit theoretical basis as long as there is a clear understanding of the behavioral determinants that each strategy is promoting. The compiled list of PT strategies can also guide intervention design and systematic review and analyses of existing PT interventions.

6. Limitations

Although our results can inform the design and study of PT interventions for health, there are limitations of applying the results of our model. First, as previously mentioned, there is no definitive list of persuasive strategies. As a result, we compiled strategies from multiple sources; however, our list is by no means exhaustive. Second, although we categorized the strategies using already existing categories, the mapping of persuasive strategies to various categories and the mapping of determinants to persuasive strategies were partly achieved using an affinity mapping exercise. Therefore, the various mapping processes are subject to interpretation. Finally, we apply the result of our models at a population level (cultural groups and sub-groups). Therefore, just like all population-based tailoring, our results will apply to the majority of the population; however, there may be outliers who do not respond in the predicted manner. Our proposed guidelines will be most suitable for developing interventions with the main aim of promoting health by motivating behavior change as opposed to commercial benefit.

Although our work benefited from the large-scale study of eating behavior of collectivists and individualists, we cannot assume the validity of our models in other health behavior domains (e.g., physical activities). Therefore, our models' results should be applied with caution in other health behavior domains. However, the underlying principle of mapping determinants to persuasive strategies and tailoring to cultural groups and sub-groups can be applied in any health behavior domain. Although culture, gender, and age have been proven as important characteristics for tailoring persuasive interventions, other demographic

factors such economic status or religious beliefs might moderate the influence of the six HBM's determinants on healthy eating behavior. Again, our study is a first step toward developing comprehensive guidelines for designing culturally relevant PT for motivating healthy eating based on theoretical determinants and we have only considered the six determinants highlighted by HBM. The determinants are by no means exhaustive; certain motivational determinants that may be more collectivist or individualist oriented may be missing. Finally, similar to most large-scale population-based research, our study is based on self-reported data and may not accurately describe peoples' actual health behavior. We focused our models on the role of the determinants in healthy eating intentions (best gathered through self-report); however, modeling the role of the determinants in healthy eating behaviors (gathered objectively) would be of interest.

7. Future work

This paper represents a step towards developing culturally relevant PT applications for motivating healthy behavior and therefore, opens opportunities for future research. Research should validate our results in other health behavior domains (e.g., physical activity, smoking cessation) to investigate possible changes in the influence of the determinants for various cultural groups and sub-groups. Our results highlighted differences in the interaction between the six determinants and healthy eating behavior for various groups and provided persuasive profiles based on the six determinants. However, there is need for a more comprehensive list of persuasive profiles comprised of determinants that motivate various groups to adopt healthy eating behavior. Future studies should therefore examine the impact of various health behavior theories and associated determinants on each group. Furthermore, an investigation of possible moderating effect of economic status might be necessary to further establish the validity of our results across various cultural groups. Again, it is also necessary to conduct a detailed qualitative study to elucidate on the possible reasons behind the results from our quantitative study. Finally, realizing the full potential of our proposed guidelines would require using our models in further research to guide decisions on PT interventions – implementing, deploying, evaluating, and reflecting on PT interventions based on our models is an important step to validate the prescriptive use of our guidelines. Therefore, we aim to apply our guidelines in the design and evaluation of PT for motivating healthy eating behavior to investigate whether PT tailored to various cultural groups and sub-groups using our results will be more effective at motivating healthy eating behavior.

8. Conclusions

Persuasive technologies for health aim to change behavior. Over the past decades, several PT applications have been developed that aim to promote healthy eating behavior by manipulating various health determinants and PT strategies. However, these applications are generally developed and evaluated in individualistic countries. As a result, little evidence exists on how to make PT appropriate for collectivists. Therefore, there is an increasing adoption of a one-size-fits-all approach that is biased towards individualist cultures. Our work is a step towards designing culturally relevant PT interventions. We provide a practical guide for applying and tailoring theoretical determinants of healthy eating behavior in PT intervention design. Our models revealed some differences between various cultural groups and sub-groups and we discussed these differences from the

perspective of healthy eating and PT intervention design. We also developed a personalized persuasive profile of what motivates different culture, gender, and age groups, and mapped these theoretical motivators to related persuasive strategies. Through our study, we exposed the limitations of the current approaches to persuasive intervention design, and presented design opportunities for both a one-size-fits-all and a personalized approach to PT intervention design that is both theory and data-driven. We argue that for PT interventions to achieve the objective of promoting healthy eating behavior, they must be culturally relevant, which could be achieved by tailoring the determinants of healthy eating behavior in accordance with our models.

To the best of our knowledge, this study is the first to examine the combined effects of culture, gender, and age on healthy eating and to develop culturally relevant guidelines for PT interventions on healthy eating. Our data-driven and culturally relevant design approaches are immediately actionable for designers to build effective PT interventions for promoting healthy eating behavior.

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