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RESEARCH ARTICLE

Developing Culturally Relevant Design Guidelines for Encouraging Physical Activity: a Social Cognitive Theory Perspective

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Abstract The prevalence of physical inactivity and non-communicable diseases is on the rise worldwide. This calls for a systematic approach in addressing the problem, which is almost becoming a global epidemic. Research has shown that theory-driven interventions are more likely to be effective than uninformed interventions. However, research on the determinants of physical activity and the moderating effect of culture is scarce. To bridge this gap, we conducted a large-scale comparative study of the determinants of physical activity among 633 participants from individualist and collectivist cultures. Using the Social Cognitive Theory, a widely applied behavioral theory in health interventions, we modeled the determinants of physical activity for each culture and mapped them to implementable strategies in the application domain. Our structural equation model shows that, in the individualist culture, *Self-Efficacy* ($\beta_T = 0.55$, $p < 0.001$) and *Self-Regulation* ($\beta_T = 0.33$, $p < 0.001$) are the strongest determinants of *Physical Activity*. However, in the collectivist culture, *Social Support* ($\beta_T = 0.42$, $p < 0.001$) and *Outcome Expectation* ($\beta_T = 0.11$, $p < 0.01$) are the strongest determinants of *Physical Activity*. We discussed these findings, mapped the respective behavioral determinants to the corresponding persuasive strategies in the health domain and provided a set of general design guidelines for tailoring the strategies to the respective cultures.

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1 Introduction

The prevalence of physical inactivity and its attendant health problems are on the increase worldwide [1]. In particular, the lack of regular physical activity, sedentary lifestyle and unhealthy eating habits have led to an increase in the number of overweight and obese people around the world, with the global prevalence of obesity from 1980 (5% of men and 8% of women) to 2008 (10% of men and 14% of women) nearly doubling. Ultimately, physical inactivity has led to an increase in the risk of morbidity and mortality as a result of the ever-increasing global body mass index. According to the World Health Organization, 2.8 million people die annually as a result of diseases related to overweight and obesity [2]. Moreover, the ever-growing health problems and chronic diseases due to physical inactivity have led to a corresponding increase in national spending on healthcare worldwide. This has led health experts to predict that the increasing incidence of health problems related to physical inactivity, if not checked, may strain the healthcare system in years to come. For example, in Canada, the healthcare cost due to sedentary lifestyle and its attendant health problems amounted to $6.8 billion in 2009—about 3.7% of all healthcare costs in Canada in that year [3]. In China, 2.4% of the national healthcare cost is spent annually on tackling health problems associated with overweight and obesity [4]. Globally, the estimated healthcare cost in 2013 amounted to INT$53.8 billion. Furthermore, physical inactivity has been associated with productivity losses in the labor market. For example, deaths related to physical inactivity were found to contribute to $13.7 billion productivity losses, with physical inactivity accounting for 13.4 million DALYs[1] globally. While high-income countries have been found to bear a larger proportion of the *economic* burden (80.8% of healthcare costs and 60.4% of indirect costs), low- and middle-income countries, in contrast, bear a larger proportion of the *disease* burden (75.0% of DALYs) [7].

Research [8–11] has shown that one of the most effective ways to reduce the ever-increasing healthcare cost due to sedentary lifestyle and obesity is to prevent associated chronic diseases as early as possible by getting people to adopt an active lifestyle and supporting them to realize their health goals. In the field of digital health, persuasive technology (PT) has been identified as an effective tool to promote behavior change, which is beneficial to the individual and the society in general. PT refers to an interactive application, which is intentionally designed to change attitudes and behaviors through persuasion and social influence—without coercion or deception [12]. Evidence abounds in the literature [13, 14] on how PT has been successfully utilized in various domains to change unhealthy behaviors such as smoking [15], unhealthy eating [16, 17], binge drinking [18–20], physical

[1] DALYS (Disability Adjusted Life Year) is a measure of the overall disease burden, expressed as a cumulative number of years lost due to non-fatal illness, disability and premature mortality. It is the sum of the Years Lived with Disability (YLD) and Years of Life Lost (YLL) due to premature death. It is used to compare the overall health of a community or country over time [5, 6].

inactivity [21, 22], etc. Though many persuasive apps have been developed to promote physical activity, a large number of such applications adopt the one-size-fits-all approach [14]. Moreover, they focus on users and contexts in developed countries [13], such as the United States [23–25], and fail to consider the moderating effect of essential demographic factors such as culture [26].

However, research [26, 27] has shown that cultural differences can affect how people from different cultural backgrounds perceive, respond to and interact with persuasive systems. As a result, persuasive applications primarily designed with the Western culture in mind may not be effective in other cultures [28]. This has necessitated the call for the personalization and adaptation of PTs based on the cultural dimension [23]. So far, in PT research, Hofstede's [29, 30] cultural framework of individualism vs. collectivism has been widely adopted as a basis for personalizing behavior change applications along the cultural dimension [31]. In addition, there have also been calls for the use of theory and empirical evidence to inform PT design and interventions as they are more likely to be successful [32, 33]. However, most persuasive applications currently in the marketplace have been designed without theoretical and/or empirical backing, neither have they been designed considering the moderating effect of culture. Rather, they have been designed based on the intuition and designer-defined requirements as well as bearing the Western target audience in mind. Yet, these persuasive applications, given the global access to the Internet by all, are being used by different users from different countries and cultures. Hitherto, in the physical activity domain, few studies on the theoretical determinants of physical activity and the moderating effect of culture have been conducted. Moreover, there is a lack of a comprehensive design guideline on how the Social Cognitive Theory (SCT) determinants of physical activity behavior can be mapped to the application domain in the context of PT [34].

To bridge the gap in the body of knowledge, we conducted a cross-cultural comparative study among members of individualist and collectivist cultures using an individualist culture (a Canadian university) and a collectivist culture (a Nigerian university and a Chinese university) as a case study. Specifically, we investigated the determinants of physical activity ($n = 633$) using the SCT model as a theoretical framework for analyzing the similarities and differences between both types of culture. We chose the SCT because of its wide application in the health domain to promote health outcomes such as weight loss, smoking cessation, etc. [34]. Moreover, we chose the SCT because of its recognition of the *Physical Environment* construct as a determinant of physical activity [35]. The results of our structural equation modeling (SEM) [36] show that, in the individualist culture, *Self-Efficacy* ($\beta_T = 0.55$, $p < 0.001$) and *Self-Regulation* ($\beta_T = 0.33$, $p < 0.001$) are the strongest determinants of *Physical Activity*. However, in the collectivist culture, *Social Support* ($\beta_T = 0.42$, $p < 0.001$) and *Outcome Expectation* ($\beta_T = 0.11$, $p < 0.01$) are the strongest determinants of *Physical Activity*. We mapped these theoretical determinants to persuasive strategies in the PT domain and recommended a number of culturally relevant guidelines for designing persuasive applications to promote physical activity in the different cultures.

The rest of this paper is organized as follows. Section 2 and Section 3 focus on background and related work, respectively. Section 4 and Section 5 present the research methodology and results, respectively. Section 6 focuses on discussion, while Section 7 focuses on conclusion and future work.

2 Background

In this section, we provide an overview of the main terminology used in this paper, which include SCT (and its theoretical constructs) and culture (and the concepts of individualism and collectivism).

2.1 Social Cognitive Theory

The SCT is a behavioral theory proposed by Bandura [37] to explain human behavior and its regulation in a social context. The theory explains "*how people regulate their behavior through control and reinforcement to achieve goal-directed behavior that can be maintained over time*" [38]. The SCT began as Social Learning Theory (SLT) in the 1960s [39] and developed into the SCT in 1986 [38]. The SLT posits that learning happens within a social context through the interplay of *personal*, *behavioral* and *environmental* factors [40]. In other words, social learning is mediated by cognitive processes, which occur within the individual, and shaped by environmental factors. Table 1 shows some of the key determinants of behavior in the SCT model and their definitions. They include *Self-Efficacy*, *Self-Regulation*, *Outcome Expectation*, *Social Support* and *Physical Environment*.

Bandura [41] theorizes that human behaviors are regulated by forethought. He expounds two main cognitive processes that control human behaviors: *Self-Efficacy* and *Outcome Expectation*s. *Self-Efficacy* refers to the belief in one's ability to perform a behavior, while *Outcome Expectation* refers to the perceived consequences of one's behavior. According to Bandura [41], as explained by Resnick [45], these expectations, which are dynamic in nature, are appraised and improved by four mechanisms. The first mechanism is known as *mastery experience*. This refers to previous success achieved in an attempt to perform the exact or similar behavior. The second is *verbal/social persuasion*, which refers to the encouragement received from other people, including credible and expert sources. The third is *vicarious experience*, which

Table 1 SCT constructs and their definitions [41–44]

SCT Construct	Definition
Self-Efficacy	*Self-Efficacy* **is** the belief in one's ability to successfully perform a behavior. It is known as the strongest and most consistent, proximal predictor of *Physical Activity*.
Self-Regulation	*Self-Regulation* is the exercise of influence overs one's behavior. It includes the management and control of one's thoughts, feelings, motivations and actions towards achieving one's behavioral goals.
Outcome Expectation	*Outcome Expectation* is a person's judgment of the possible consequences (positive or negative) of a given course of action or behavior. It is of three types: *physical outcomes*, *social outcomes* and *self-evaluative outcomes*.
Social Support	*Social Support* is the support a person receives from society (e.g., friends and family) as a form of encouragement towards performing a target behavior.
Physical Environment	*Physical Environment* refers to the physical environmental facilities (e.g., recreational facilities, active transportation systems, safe neighborhood, etc.) which promote or facilitate the performance of physical activity.

entails observing and learning from similar others performing the target behavior successfully. The fourth mechanism is *physiological and emotional states*, which refer to a person's feelings in the face of a given task or activity, e.g., fatigue, pain, anxiety, etc. [42, 45]. Bandura [42] also identifies *Self-Regulation* (the ability to regulate one's thoughts, actions and emotions) as a cognitive process that shapes human behavior. Apart from these cognitive processes (*Self-Efficacy*, *Outcome Expectation* and *Self-Regulation*), the SCT recognizes external factors as determinants of behavior as well [43]. Specifically, it recognizes *Social Support* and *Physical Environment*, which other behavioral theories, such as the traditional Health Belief Model (HBM), do not recognize. Further, unlike some of the other behavioral theories for health promotion, the SCT emphasizes the maintenance of a behavior after its initiation and/or adoption [37]. The SCT has been extensively used for health promotion and intervention design due to its emphasis on the individual as well as the social and environment factors [38]. Its ultimate goal is to help people exercise control over several health habits so that they can live longer, healthier, and slow the biological aging process [43].

2.2 Culture

Culture is defined as "*the collective programming of the mind which distinguishes the members of one group or category of people from another*" (p. 5) [30]. Culture has been identified as an important factor in Human-Computer Interaction (HCI) design [46]. It plays an influential role in shaping the attitudes and behaviors of PT users before and after persuasion, depending on how important the target behavior is to the target culture. Specifically, the cultural background of the recipient of a persuasive message plays a significant role in how s/he perceives or receives it [25]. Among the different classifications of culture available in the literature, *individualism* vs. *collectivism* remains one of the widely adopted and applied cultural dimensions in HCI and PT research. This is as a result of the direct bearing it has on the link between system design and user behavior [31]. Moreover, a substantial amount of research has shown that the individualism vs. collectivism dimension of culture can explain most of the variance in global differences [25]. This forms the basis for our choosing this cultural dimension as a conceptual framework to investigate the moderating effect of culture with regard to the SCT determinants of physical activity.

2.2.1 Individualist Culture

Individualism is the world view of the self as an independent entity, which possesses a set of self-defining attributes, resulting in the expression of personal opinions and beliefs and the pursuits of personal goals and aspirations. Thus, in this type of culture, the concept of "I" as a distinct individual takes precedence over the concept of "We" as a collective group. As a result, members of this type of culture put their personal interests first as opposed to the collective interests. It is believed that in individualist culture everyone has to take care of him/herself first and his/her immediate family at most and has the right of privacy. It is also believed that the individual's tasks and achievements should prevail over social relationships. Ultimately, the view of the self as independent and self-reliant and the need to prioritize personal interests above

collective interests influence how the individual relates with others in the society. For example, relationships among people are based on the assumption that they have to be made freely and with little or no obligation to the other party involved. Most countries in Western cultures, such as United States, Canada, Germany, etc., are classified as individualist societies [29, 30, 47].

2.2.2 Collectivist Culture

Collectivism is the world view of the self as an interdependent entity and belonging to an in-group, which members owe an obligation, such as complying with its norms and ethos. In this type of culture, members are expected and obligated to pursue the collective goals and aspirations of the in-group (as opposed to personal goals) through consensus and compromise. Thus, unlike the individualist culture, the concept of "We" as a collective takes precedence over the "I" as an individual. In other words, people put the collective interests ahead of their personal interests. In the in-group, the opinions of others have a strong influence on the decision-making of its members. Secondly, members are bound to be loyal to the leadership of the in-group in exchange for protection and other benefits. Thirdly, social relationships prevail over individual tasks. Most countries in Africa, Asia and South America (e.g., Nigeria, China, Brazil, etc.) are classified as collectivist societies [29, 30, 47].

3 Related Work

Research [32, 33] has shown that health interventions which are informed by theory are more likely to succeed than those that are uninformed. In this section, we reviewed a number of empirical studies, health interventions and guidelines based on commonly used behavioral theories. We also identified some of the gaps in the extant literature.

3.1 SCT Models of Physical Activity

The SCT has been extensively used to model the determinants of physical activity, especially in Western and Asian cultures [48]. Rovniak et al. [44] modeled the SCT determinants of physical activity among 277 university students from Virginia Polytechnic Institute and State University in the United Sates. Their SEM model accounted for 55% of the variance of *Physical Activity*. They found that *Self-Efficacy* had the strongest total effect on *Physical Activity*, followed by *Self-Regulation* and *Social Support*. However, they found that *Outcome Expectation* had no significant direct or total effect on *Physical Activity* when *Self-Efficacy* was controlled for in the SCT model. Resnick [45] also modeled the SCT determinants of physical activity among 201 older adults in the United States, who were living in a continuing care retirement center. Their model accounted for 40% of the variance of *Current Exercise*, with *Self-Efficacy*, *Outcome Expectation* and *Prior Exercise* directly influencing *Current Exercise*. Furthermore, Anderson et al. [49] modeled the SCT determinants of physical activity among 999 adults from 14 Southwestern Virginia churches in the United States. Their model accounted for 46% of the variance of *Physical Activity*, with *Age*, *Race*, *Social Support*, *Self-Efficacy* and *Self-Regulation* (excluding *Outcome Expectation*) having a

significant effect on *Physical Activity*. Specifically, *Self-Regulation* had the strongest effect on *Physical Activity*; *Self-Efficacy* had little direct effect without the mediating effect of *Self-Regulation*. Moreover, *Social Support* influenced *Physical Activity*, with *Self-Efficacy* and *Self-Regulation* acting as mediators. Finally, Haider and Sharma [50] modeled the physical activity of South Asian population in the United States based on a sample of 58 college students. Their model accounted for 8.2% of *Exercise Behavior*, with only *Self-Efficacy* having a direct influence on *Exercise Behavior*. Finally, Oyibo [51] conducted a comparative study among university students resident in Canada and Nigeria to investigate the SCT determinants of physical activity. The author found that *Self-Efficacy* and *Self-Regulation* were the strongest determinants of *Physical Activity* for the Canadian group, while *Social Support* and *Body Image* were the strongest determinants of *Physical Activity* for the Nigerian group.

3.2 Health Interventions

Research [32, 33, 52] has shown that health interventions, which specifically target causal determinants, are more likely to be successful than those that do not. In this section, we reviewed PT interventions and existing design guidelines based on behavioral determinants. Finally, we identified some of the gaps in the existing literature.

3.2.1 Theory-Based Design Guidelines

A number of health science and PT researchers have proposed a number of health intervention design guidelines, which are mapped to behavioral determinants in the field of psychology. Michie et al. [33] presented a mapping of 11 theoretically derived behavioral determinants to 35 relevant behavior change techniques. The determinants include *Skills*, *Capabilities*, *Motivation/Goals*, *Action Planning*, *Consequences*, *Memory*, *Emotion*, *Social Influence*, *Role/Identity*, *Environment* and *Knowledge*. On the other hand, some of the behavior change techniques to which they are mapped include Self-Monitoring, Rewards, Graded Task, Role Play, Prompts/Triggers/Cues, Personalized Message, Time Management, etc. However, the determinants they covered are generic. In other words, they are not specifically associated with a given behavioral theory, neither are they targeted at motivating behavioral change in the context of PT. Further, in the PT domain, Orji and Mandryk [26] carried out a study to investigate the theoretical determinants of healthy eating in individualist and collectivist cultures using the HBM as a theoretical modeling framework. They found that *Self-Efficacy*, *Perceived Susceptibility*, *Perceived Severity*, *Perceived Benefit* and *Perceived Barrier* are the strongest determinants of *Health Eating* among individualists, while *Perceived Benefit* is the strongest determinant of *Health Eating* among collectivists. They went further to recommend a number of design guidelines based on the significant determinants to guide the design of PT interventions. However, the authors' investigation focused on the eating domain. Moreover, it was not based on the SCT; thus, it did not consider external factors such as *Social Support* and *Physical Environment*. Finally, Yoganathan and Kajanan [34] proposed a set of design guidelines for developing successful fitness applications based on the SCT model. Using data collected from fitness app users on iTunes, they mapped four determinants of successful fitness applications (*Self-Efficacy*, *Self-Regulation*, *Outcome Expectation* and *Social*

Facilitation) to their corresponding persuasive strategies. However, the authors did not focus on *Physical Activity* as the target behavior but rather on *Fitness App Success*. They neither examined the *Physical Environment* construct in their SCT model nor the moderating effect of culture.

3.2.2 Culture-Based PT Intervention Evaluation

Personalizing PT interventions to user characteristics has received wide attention—both in the research and application domains. However, in the health domain, very few studies have been conducted on the influence of culture on the effectiveness of PT interventions. In our literature review, we were only able to come across one evaluation study of a health intervention called "*Smoke?*," which investigated the moderating effect of culture. The intervention was aimed at fostering smoking cessation among smokers. Specifically, Khaled et al. [15, 53] investigated how relevant cultural background is in tailoring *Smoke?*—a game-based app—towards having the intention to quit smoking. Thus, the authors developed two versions of the game: one tailored for the individualist culture and the other tailored for the collectivist culture. The results of their evaluation showed that both versions of the game were effective in bringing about favorable behavioral change in both cultures. Specifically, each version was more effective among the players of the respective culture for which it was designed.

3.3 Research Gaps in Prior Literature

Based on our literature review, we found that most of the SCT-based studies have been conducted in individualist cultures such as the United States [25]. Collectivist cultures in continents, such as Africa, where the problem of physical inactivity and obesity is becoming a global epidemic [8, 54]—due to the rapidly changing dietary and physical activity patterns—have been barely studied [13]. Similarly, comparative studies aimed at tailoring PT interventions based on culture in the physical activity domain are scarce.

Secondly, according to a meta-analysis by Young et al. [48], "*the majority of SCT research has focused solely upon self-efficacy or examined self-efficacy in combination with only one or two other variables*" (p. 985). In particular, the *Physical Environment* construct has been left out of most SCT models in the literature [28]. Whereas, according to the SCT, the environmental factor, which includes the physical environment, constantly interacts reciprocally with personal and behavioral factors to determine and shape human behaviors [40, 55]. Research [56–59] outside SCT has also shown that there is a strong link between the *Physical Environment* and *Physical Activity*. Yet, most studies have overlooked this important construct within the SCT framework. Hitherto, they are only a few studies in the physical activity domain showing its relationships with the core constructs of the SCT. Rather, most studies focus more on *Social Support* than *Physical Environment* as an external determinant of *Physical Activity*.

Thirdly, there are limited studies, which have provided a comprehensive set of design guidelines, showing how the theoretical determinants in the SCT model can be mapped to persuasive strategies in the application domain. For instance, the design guidelines provided by Yoganathan and Kajanan [34] for operationalizing the SCT determinants are not comprehensive enough. For example, to operationalize *Self-*

Efficacy, only Tunneling and Reduction strategies were recommended, while, to operationalize *Self-Regulation*, only Self-Monitoring and Tailoring strategies were recommended. This limits PT designers to few persuasive strategies to choose from when operationalizing the respective SCT determinants of physical activity behavior. Moreover, no persuasive strategies were recommended for the *Physical Environment* determinant (as the authors did not consider it in their study), neither was culture taken into consideration in the recommendation of persuasive strategies for the development of successful fitness applications. Consequently, our work sets out to fill in these gaps by investigating: (1) the cultural differences that exist between the individualist and collectivist cultures using the SCT as a theoretical modeling framework; and (2) providing a more comprehensive set of PT design guidelines mapped to the SCT determinants.

4 Method

To uncover the SCT determinants of physical activity and the moderating effect of culture, we adopted a quantitative research approach. We designed an SCT-based survey in which we considered six constructs: *Self-Efficacy*, *Self-Regulation*, *Social Support*, *Outcome Expectation*, *Physical Environment* and *Physical Activity* (the target construct). In this section, we briefly discussed the instruments used to measure the respective constructs, the data collection and the demographics of participants.

4.1 Data Collection

The survey was approved by the first authors' University Behavioral Research Ethics Board, after which student respondents were recruited to participate anonymously. For the individualist culture, the survey was posted on the first authors' University online bulletin for voluntary student participation. In addition, participants were invited by emails (containing a link to the survey) to take part in the study. In appreciation of participants' time, they were given the opportunity to enter for a draw to win one of three gift cards worth C$50 each. The data gathering lasted for a period of 6 months. For the collectivist culture, two sets of data were collected: one in a Nigerian university and the other in a Chinese university. In the Nigerian university, a paper-based questionnaire was administered to the participants in a classroom setting in different sessions over a 2-week period. The participants were compensated with a phone-credit card worth $0.75 in appreciation of their time. The survey in Nigeria was paper-based because of the limited access to the Internet and the challenges of low bandwidth [60], which might have prevented a number of Nigerian respondents from participating in the study were it internet-based. However, with respect to the study in China, students were invited by email to participate voluntarily in the study online. They were, however, not compensated.

4.2 Participants

In total, about 670 subjects took part in the study. After data cleaning, we were left with 633 valid participants, 218 of whom were originally from and/or resident in Canada

(individualist country) and the other 415 were from and resident in China or Nigeria (collectivist country). Table 2 shows the demographics. Participants were classified as individualist and collectivist cultures based on their country of residence since people change after living in another culture for a while through the social process known as acculturation [61]. People could also carry multiple layers of cultures (e.g., individualist and collectivist), with one being predominant at a given point in time [62]. According to Hofstede et al. [30], "*people unavoidably carry several layers of mental programming within themselves, corresponding to different levels of culture*" (p. 3). The multiple layers are determined by a number of factors, which include nationality, affiliation, social class, workplace or place of study, etc. In our study, in order not to exclude the collectivist participants who are resident in an individualist country (Canada) from the data analysis, we classified them as individualist based on the new culture in which they now lived and studied.

Table 2 Demographic characteristics of participants

Criterion	IND* ($N = 218$)			COL* ($N = 415$)		GLO ($N = 633$)	
	Subgroup	No.	Percent	No.	Percent	No.	Percent
Gender	Female	126	57.8%	155	37.3%	281	44.4%
	Male	91	41.7%	248	59.8%	339	53.6%
	Unspecified	1	0.5%	12	2.9%	13	2.1%
Age	18–24 years	107	49.1%	319	76.9%	426	67.3%
	25–34 years	86	50.0%	75	18.1%	161	25.4%
	35–44 years	16	7.3%	3	0.7%	19	3.0%
	>45 years	7	3.2%	0	0.0%	7	1.1%
	Unspecified	2	0.9%	18	4.3%	20	3.2%
Education	High School	77	35.3%	303	73.0%	380	60.0%
	Bachelor	73	33.5%	56	13.5%	129	20.4%
	Postgraduate	58	26.6%	7	1.7%	65	10.3%
	Others	10	4.6%	49	11.8%	59	9.3%
Country	Canada	122	56.0%	–	–	122	19.3%
	Nigeria	17	7.8%	292	70.4%	309	48.8%
	China	9	4.1%	123	29.6%	132	20.9%
	Others	70	3.2%	–	–	70	11.1%
Continent	North America	122	56.0%	–	–	122	19.3%
	Asia	36	16.5%	123	29.6%	159	25.1%
	Africa	26	11.9%	292	70.4%	318	50.2%
	Europe	26	11.9%	–	–	26	4.1%
	South America	3	1.4%	–	–	3	0.5%
	Middle East	2	0.9%	–	–	2	0.3%
	Unspecified	3	1.4%	–	–	3	0.5%

*IND (Individualist) and COL (collectivist) participants were defined based on country of residence; GLO = Global (general) population

4.3 Measurement Instruments

The survey design was based on existing validated instruments in the literature [44, 63–65]. All of the constructs were measured using an ordinal (Likert) scale, except for *Physical Activity*, which was based on a numerical scale. Some of the constructs are multi-dimensional (i.e., measured indirectly by using lower-order constructs (LOCs)), while others are unidimensional (i.e., measured directly by their indicators). Appendix Table 6 shows the six SCT constructs, their LOCs and example indicators. *Self-Efficacy (SE)* [63] and *Physical Environment (ENV)* [69] were directly measured, while *Social Support (SS)* [64], *Self-Regulation (SR)* [44] and *Outcome Expectation (OE)* [65] were indirectly measured. For example, *SS* was indirectly measured using the *Family* and *Friends* LOCs. Similarly, *OE* was indirectly measured using the *Self-Evaluative OE*, *Physical OE* and *Social OE* LOCs, while *SR* was indirectly measured using the *Exercise Goal Setting* and *Exercise Planning and Schedule* LOCs.Moreover, the *Physical Activity* construct was specially measured. It captures how often, how long and the type of physical activity an individual performs over a given period of time, precisely 1 week. Overall, there are three types of physical activity, which include light-, moderate- and vigorous-intensity activities, each of which is measured in MET-mins/week. MET, which stands for Metabolic Equivalent of Task [70], is a physiological measure of physical activity and is defined as the ratio of the rate of energy expended while someone is performing a physical activity to the rate of energy expended while s/he is at rest. Specifically, 1 MET is equivalent to 1Kcal/(kg x hr). Different activities have different MET values or coefficients. In our questionnaire, to measure *Physical Activity*, three different dimensions were used. They include walking (MET value = 3.3), moderate-intensity activity (MET value = 4.0) and vigorous intensity activity (MET value = 8.0). We adopted the International Physical Activity Questionnaire (IPAQ) [68] measurement instrument, which measures the physical activity of individuals in terms of walking, moderate- and vigorous-intensity activities in the last seven days. The repeatability's Spearman's rho-value of the IPAQ instrument for all three activities combined (i.e., total MET-mins/week) was about 0.75. We used Eq. 1 to calculate the MET-mins per week for each type of physical activity, with: (1) λ representing the physical activity type's MET-coefficient; (2) mins/day representing the amount of time spent in performing the physical activity per day; and (3) days/week representing the number of days per week spent in performing the activity. In calculating MET-mins/week for each activity, missing (zero) values for the walking activity for certain subjects were replaced with the respective averages based on the geographical location where each study was conducted. However, missing (zero) values for moderate- and vigorous-intensity activities were not replaced with average values, because we believed, unlike walking, it was possible for participants to have not performed these types of activities in the last 1 week as reported given that they were more demanding.

$$MET - mins/week = \lambda * \frac{mins}{day} * \frac{days}{week} \quad (1)$$

5 Results

In this section, we present the SEM analysis of the collected data, including the evaluation of the measurement models, the structural model analysis and the multigroup analysis (MGA).

5.1 Evaluation of Measurement Model

In our SEM analysis, we built three models: the global model (Fig. 1), the individualist model (Fig. 2a) and the collectivist model (Fig. 2b). The three models were built using the "plspm" package in R [71]. In all three models, we began the SEM analysis by evaluating the respective measurement models before proceeding to analyze the structural models. Firstly, we evaluated the Indicator Reliability. All of the retained indicators in the measurement models had an outer loading greater than 0.4 [72]. Over 90% of the indicators in each model had loadings greater than 0.6. Those that did not meet the "0.40 threshold" criterion were dropped from the respective models (see Appendix Table 7). For example, four and five items in *Self-Regulation* were dropped from the global and collectivist measurement models, respectively. Similarly, three items in *Physical Environment* were dropped from each of the measurement models. Secondly, we evaluated the Internal Consistency Reliability for each construct using the composite reliability criterion, which was based on DG.rho and greater than 0.7. Thirdly, we evaluated the Convergent Validity for each construct using the Average Variance Extracted, which was greater than 0.5. Finally, we evaluated the Discriminant Validity for each construct using the crossloading metric. No indicator of a given construct loaded higher on any other construct than the one it measured.

5.2 Global Structural Model

Figure 1 shows the global model for the general population (entire data). In the model, the coefficient of determination (R^2) represents the amount of variance of an

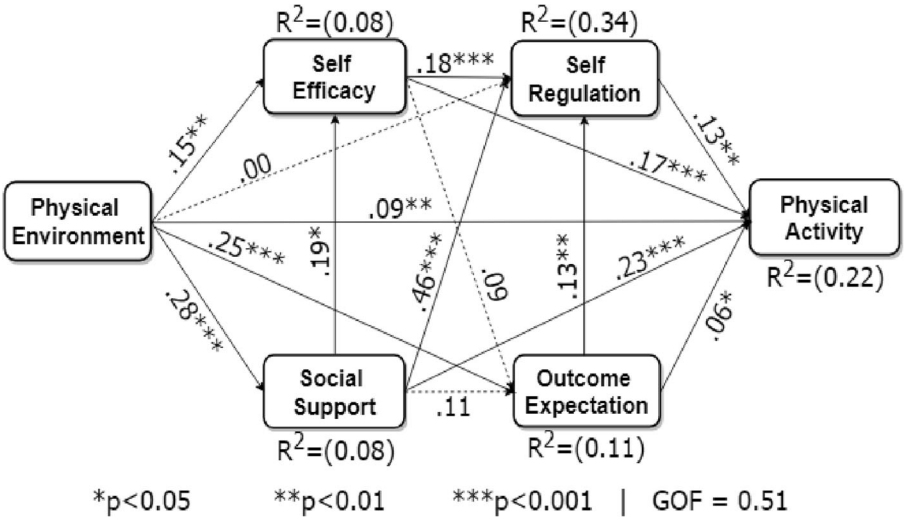

Fig. 1 Global social cognitive model

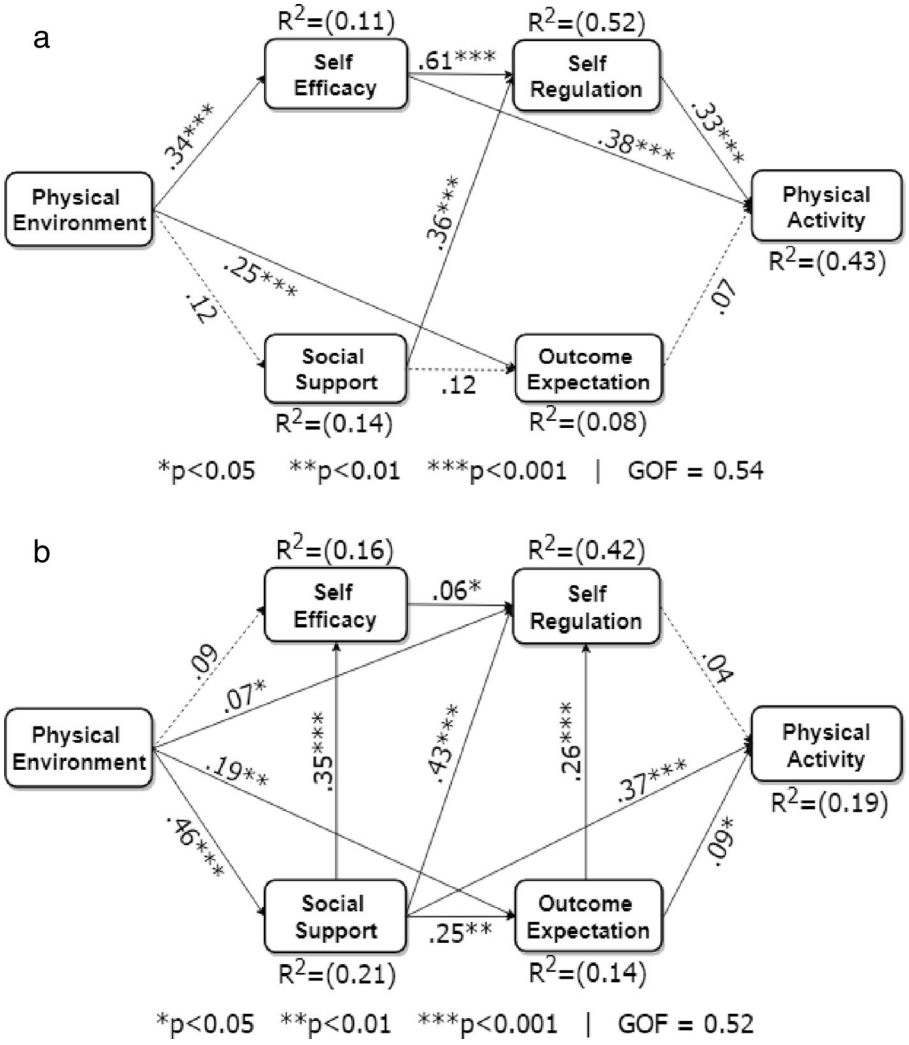

Fig. 2 **a** Individualist social cognitive model. **b** Collectivist social cognitive model

endogenous construct (dependent variable) the exogenous constructs (independent variables) are able to account for [36, 71]. The path coefficient (β), also known as the direct effect of one construct on another, denotes the strength of the relationship between two constructs. The goodness of fit (GOF) represents how well the model fits the data [71]. As shown in Fig. 1, the GOF of the global model is 51%. The model explains 22% of the variance of *Physical Activity*, with every exogenous construct contributing to the explanation. Of all the SCT determinants, *Self-Regulation* (34%) has the highest variance explained, while *Self-Efficacy* (8%) and *Social Support* (8%) are least explained by their exogenous constructs. Twelve (12) of the 15 explored relationships in the global model are significant. The three that happened to be non-significant include the direct effect of *Physical Environment* (β = 0.00, n.s) on *Self-Regulation* and the direct effect of *Self-Efficacy* (β = 0.09, p = n.s) and *Social Support* (β = 0.11, p =

n.s) on *Outcome Expectation*. Moreover, with respect to the target construct, *Social Support* ($\beta = 0.23$, $p < 0.001$), followed by *Self-Efficacy* ($\beta = 0.17$, $p < 0.001$) and *Self-Regulation* ($\beta = 0.13$, $p < 0.01$), exerts the strongest direct effect on *Physical Activity*, while *Physical Environment* ($\beta = 0.09$, $p < 0.01$) and *Outcome Expectation* ($\beta = 0.06$, $p < 0.05$) exert the weakest direct effects on *Physical Activity*.

5.3 Culture-Based Structural Models

To understand how culture moderates the relationships between the constructs in the SCT model, we built and analyzed two culture-specific models (individualist model and collectivist model) and conducted MGA afterwards.

5.3.1 Individualist Structural Model

Figure 2a shows the individualist SCT model. Overall, the model accounts for 43% of the variance of *Physical Activity*, with *Self-Efficacy* and *Self-Regulation* being responsible for most of the variance explanation. *Outcome Expectation* virtually contributes nothing to the explanation of *Physical Activity* due to its non-significant effect ($\beta = 0.07$, $p =$ n.s) on the target construct. Moreover, of the significant relationships, *Self-Efficacy* has the strongest direct effect ($\beta = 0.61$, $p < 0.001$) on *Self-Regulation*, followed by its direct effect ($\beta = 0.38$, $p < 0.001$) on *Physical Activity*. On the other hand, *Physical Environment* has the weakest direct effect ($\beta = 0.25$, $p < 0.001$) on *Outcome Expectation*, followed by the direct effect of *Self-Regulation* ($\beta = 0.33$, $p < 0.001$) on *Physical Activity*.

5.3.2 Collectivist Structural Model

Figure 2b shows the collectivist SCT model. Overall, the model accounts for 19% of the variance of *Physical Activity*, with *Social Support* being responsible for most of the variance explanation. *Outcome Expectation* makes a very little contribution, while *Self-Regulation* barely contributes to the variance explanation of *Physical Activity* due to its non-significant effect. As shown in the model, among all the exogenous SCT constructs, *Social Support* is most influential and has the strongest influence on the other (four endogenous) constructs. Beginning with the strongest influence, *Social Support* has a direct effect on *Self-Regulation* ($\beta = 0.43$, $p < 0.001$), *Physical Activity* ($\beta = 0.37$, $p < 0.001$), *Self-Efficacy* ($\beta = 0.35$, $p < 0.001$) and *Outcome expectation* ($\beta = 0.25$, $p < 0.01$). Moreover, *Physical Environment*, which is the second most influential construct in the model, has the strongest direct effect on *Social Support* ($\beta = 0.46$, $p < 0.001$), followed by *Outcome Expectation* ($\beta = 0.19$, $p < 0.01$) and *Self-Regulation* ($\beta = 0.07$, $p < 0.05$). Finally, *Self-Efficacy* and *Self-Regulation*, which had significant direct effects on *Physical Activity* in the individualist model, turn out to have no significant direct effect on the target construct in the collectivist model.

5.4 Multigroup Analysis

To uncover the possible significant differences between the individualist and collectivist models with respect to the direct effects, we conducted an MGA. The MGA was based on the global model because our subgroup models are not structurally identical and the

global model contains all of the possible relationships. The MGA was used to compare the corresponding path coefficients of the direct effects in the individualist and collectivist models. The results of the MGA (see Table 3) show that there are eight significant differences between the path coefficients of the individualist model and those of the collectivist model. For example, the relationship between *Self-Efficacy* and *Physical Activity* is significantly different ($p < 0.001$) in both models. Similarly, the relationship between *Self-Regulation* and *Physical Activity* is significantly different ($p < 0.01$) in both models. Specifically, *Self-Efficacy* and *Self-Regulation* have a significant direct effect on *Physical Activity* in the individualist model, but a non-significant direct effect in the collectivist model. In contrast, the relationship between *Social Support* and *Self-Efficacy* or *Physical Activity* is significantly different ($p < 0.01$) in both models. While *Social Support* has a significant direct effect on *Self-Efficacy* and *Physical Activity* in the collectivist model, it has a non-significant direct effect in the individualist model.

5.5 Total Effect of SCT Determinants on Physical Activity

Figure 3 shows the total effect (β_T) of the exogenous SCT constructs on *Physical Activity*. In the individualist model, *Self-Efficacy* ($\beta_T = 0.55, p < 0.001$) and *Self-Regulation* ($\beta_T = 0.33, p < 0.001$) have the strongest total effect on *Physical Activity*. In contrast, in the collectivist model, *Social Support* ($\beta_T = 0.42, p < 0.001$) has the strongest total effect on *Physical Activity*. However, in the individualist model ($\beta_T = 0.17, p < 0.001$) and collectivist model ($\beta_T = 0.21, p < 0.001$), *Physical Environment* has an approximately equal total effect on *Physical Activity*. *Outcome Expectation* ($\beta_T = 0.10, p < 0.01$) turns out to have a significant total effect on *Physical Activity* in the collectivist model only. It is

Table 3 Multigroup analysis showing the direct-effect differences between individualist and collectivist cultures

Direct Effect	GLO (633)	IND (218)	COL (415)	Diff p-val	Diff Sig?	Remark
SE → SR	.18***	.61***	**.06***	.001	✓	***SE influences SR for IND, but weakly for COL***
SE → OE	-	-	-	n.s	×	No difference between IND and COL
SE → PA	.17***	.38***	-	.001	✓	***SE influences PA for IND, but not for COL***
SR → PA	.13**	.33***	–	.01	✓	***SR influences PA for IND, but not for COL***
SS → SE	.19*	-	.35***	.01	✓	***SS influences SE for COL, but not for IND***
SS → OE	-	-	.25**	n.s	×	No difference between IND and COL
SS → SR	.46***	.36***	.43***	n.s	×	No difference between IND and COL
SS → PA	.23***	-	.37***	.01	✓	***SS influences SE for COL, but not for IND***
OE → SR	.13**	-	.26***	.01	✓	***OE influences SR for COL, but not for IND***
OE → PA	.06*	-	.09*	n.s	×	No difference between IND and COL
ENV → SR	-	-	.07*	n.s	×	No difference between IND and COL
ENV → OE	.25**	.25***	.19**	n.s	×	No difference between IND and COL
ENV → SE	.15**	.34***	-	.05	✓	***ENV influences SE for IND, but not for COL***
ENV → SS	.28***	-	.46***	.001	✓	***ENV influences SS for COL, but not for IND***
ENV → PA	.09**	-	-	n.s	×	No difference between IND and COL

GLO = global model, IND = Individualist model, COL = Collectivist model, Diff = Difference, Sig = Significant, n.s = Non-significant, PA = Physical Activity, SE = Self-Efficacy, SR = Self-Regulation, OE = Outcome Expectation, SS = Social Support, ENV = Physical Environment; the bolded remark indicates a significant difference between the two cultural groups

noteworthy that the total effects, to a large extent, reflect the MGA findings in Table 3. For example, in the MGA, we found that *Self-Efficacy* and *Self-Regulation* have significant direct effects on *Physical Activity* in the individualist model but not in the collectivist model. Similarly, in Fig. 3, we found that the total effects of both constructs on *Physical Activity* are significant in the individualist model only. On the other hand, in the MGA, we found that *Social Support* and *Outcome Expectation* have significant direct effects on *Physical Activity* in the collectivist model, but not in the individualist model. This is replicated in the significant total effect of *Outcome Expectation* on *Physical Activity* in the collectivist model only and the stronger total effect of *Social Support* on *Physical Activity* in the collectivist model than in the individualist model.

6 Discussion

We have presented, using exploratory approach, three SEM models showing the interrelationships among six constructs of the SCT in the physical activity domain. It is worthy of note that, in the three models presented, more variance of *Physical Activity* is explained when the individualist group is modeled differently from the general population. In particular, the explained variance of *Physical Activity* increases from 22% in the global model to 43% in the individualist model. This is an indication that the individualist sample is more homogeneous than the entire population sample, which comprises individualist and collectivist members (a heterogeneous sample). This, coupled with the fact that the interrelationships among *Self-Efficacy*, *Self-Regulation* and *Physical Activity* are stronger in the individualist model, is a clear indication that the two cultural groups are different and thus need to be modeled differently. Meanwhile, the fact that, in the collectivist model, only 19% of *Physical Activity* is explained, mainly by *Social Support*, shows that there are other factors that are not

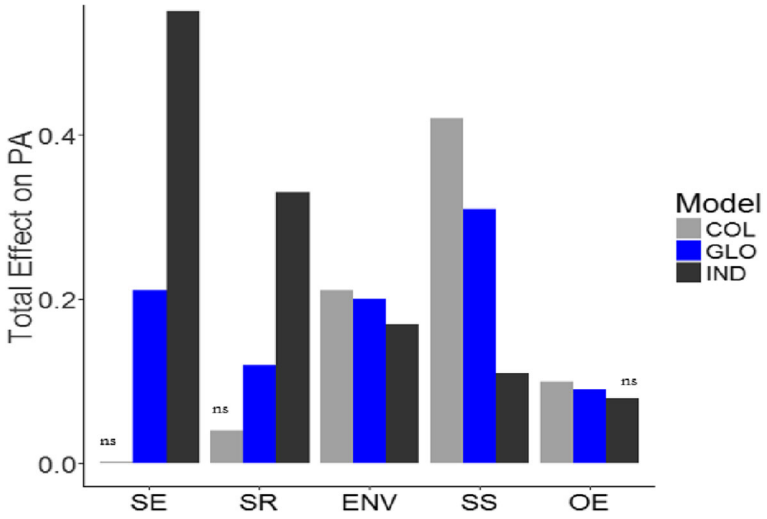

Fig. 3 Total effect of SCT determinants on physical activity (n.s = non-significant, GLO = global model, IND = Individualist model, COL = Collectivist model, SE = Self-Efficacy, SR = Self-Regulation, OE = Outcome Expectation, SS = Social Support, ENV = Physical Environment, PA = Physical Activity)

captured in the model, which may account for the variance of the target construct. However, the fact that four of the five relationships between *Social Support* and the other constructs are stronger in the collectivist model than in the global model is an indication that the collectivist group forms a more homogenous sample than the entire population sample. Moreover, the MGA specifically shows that the individualist and collectivist groups are significantly different (see Table 3). Thus, there is a need for the recommendation of different persuasive strategies to motivate behavior change in the different cultures. We discuss our findings in details in the following subsections and map the respective SCT determinants of physical activity in each culture-specific model to the corresponding (implementable) persuasive strategies in the PT domain.

6.1 SCT Determinants of Physical Activity Profile

Table 4 summarizes the SCT determinants of physical activity profile for the general, individualist and collectivist populations, starting from the strongest to the weakest determinants. Overall, based on the total effect analysis (see Fig. 3), *Social Support*, *Self-Efficacy* and *Physical Environment* emerged as the strongest determinants of *Physical Activity* for the general population, with *Social Support* being the strongest in the collectivist model and *Self-Efficacy* being the strongest in the individualist model. These findings are consistent with some of the findings in prior studies. For example, Gu et al. [74] found that the *physical activity* of college students positively correlated with their *self-efficacy* as well as their *attraction to group tasks and goals*. This indicates that, at the global level, *Social Support* and *Self-Efficacy* are significant drivers of physical activity behavior, with collectivist members being more motivated by the former and individualist members by the latter. Moreover, we find that the *Physical Environment* is an important driver as well, irrespective of culture. In particular, the total effect of the *Physical Environment* on *Physical Activity*—via mediating constructs such as *Self-Efficacy* (in the individualist model) and *Social Support* (in the collectivist model)—is significant.

A critical look at Table 4 reveals that the physical activity of participants in the individualist culture is driven mostly by personal factors (*Self-Efficacy* and *Self-Regulation*), while that of participants in the collectivist culture is driven mostly by social factors (*Social Support*). Interestingly, these findings are consistent with the theoretical framework of individualism and collectivism, proposed by Hofstede [29, 30], in which individualists are independent and self-motivated, while collectivists are socially oriented [25, 29, 75]. Specifically, the individualist-related finding is consistent with the main findings of Young et al.'s [48] meta-analytic review, which was mostly based on studies conducted in individualist cultures. In the meta-analysis, the authors found that *Self-Efficacy* and *Self-Regulation* were the most consistent SCT determinants of *Physical Activity*, while *Outcome Expectation* and socio-structural factors (e.g., *Social Support*) were not significant determinants.

Furthermore, situating the main findings within the context of Bandura's [40] reciprocal determinism framework, in which human behavior is modeled as an interplay of *personal* (cognitive, affective, and biological), *environmental* (physical and social) and *behavioral* factors, we proposed an abstract model (see Fig. 4) to summarize our main findings. Given that, in the individualist model, *Self-Efficacy* and *Self-Regulation* are the strongest determinants of *Physical Activity* (with their total effects exceeding 0.20 and twice the collectivist values, as shown in Fig. 3), we represented them as "*Personal Factors*" in our abstract model. Moreover, given that in the individualist model (see Fig.

Table 4 SCT determinants of physical activity profile for the global and culture-specific populations

Model	Significant SCT determinants of physical activity in decreasing order of strength
Global	*Social Support*, *Self-Efficacy*, *Physical Environment*, *Self-Regulation*, *Outcome Expectation*
Individualist	*Self-Efficacy*, *Self-Regulation*, *Physical Environment*, *Social Support*, *Outcome Expectation*$^{n.s}$
Collectivist	*Social Support*, *Physical Environment*, *Outcome Expectation*, *Self-Regulation*$^{n.s}$, *Self-Efficacy*$^{n.s}$

Superscripted constructs (n.s) indicate non-significant determinants of physical activity in respective models. The underlined (_) are the relatively strongest determinants in each group (with $\beta_T >= 0.20$, $p < 0.05$ [72, 73])

2a), *Physical Environment* directly influences *Self-Efficacy*, which in turn influences *Self-Regulation*, which in turn influences *Physical Activity*, we summarized this path to engagement in physical activity as "*Physical Environment* → *Personal Factors* → *Physical Activity*. Similarly, given that, in the collectivist model, *Social Support* is the strongest determinant of *Physical Activity* (with its total effect exceeding 0.2 and twice the individualist value, as shown in Fig. 3), we represented it as "*Social Factors*" in our abstract model. Moreover, given that, in the collectivist model (see Fig. 2b), *Physical Environment* directly influences *Social Support*, which in turn influences *Physical Activity*, we summarize this path to engagement in physical activity as *Physical Environment* → *Social Factors* → *Physical Activity*.

In summary, our abstract model suggests that, in the individualist culture, increased availability of *environmental facilities* (e.g., recreational facilities, cycling track, safe neighborhood, etc.) will lead to increased *personal factors* (such as self-efficacy and self-regulation), which in turn will lead to increased *physical activity*. On the other hand, in the collectivist culture, increased availability of *environmental facilities* (e.g., sport facilities, recreational parks, etc.) will lead to increased *social factors* (family and friends' support and engagement), which in turn will lead to increased *physical activity*. Both of these culture-specific findings are consistent with the underlying principles of individualism and collectivism. In the individualist culture, given the emphasis on personal interests and goals over those of the in-group, members of this culture tend to be independent, self-motivated and self-reliant. In contrast, in the collectivist culture, given the emphasis on the collective interests and aspirations of the in-group over those of the individuals, members of this culture tend to be interdependent, socially oriented and socially driven [29, 76]. Interestingly, in our SCT model of physical activity, we see both world views of culture play out empirically. For the individualist culture, *personal factors* (such as *self-efficacy* and *self-regulation*) turns out to be the strongest drivers of *physical activity*, while, for the collectivist culture, *social factors* (such as *social support*) turns out to be the strongest driver of *physical activity*.

6.2 Mapping of SCT Determinants of Physical Activity to Persuasive Strategies in the Application Domain

Having discussed the SCT determinants of physical activity for the two types of culture and the theoretical underpinnings, we proceed to map the respective determinants to operational strategies in the PT domain. Table 5 shows the global and culture-specific mappings of the SCT determinants of physical activity to persuasive strategies. Based on

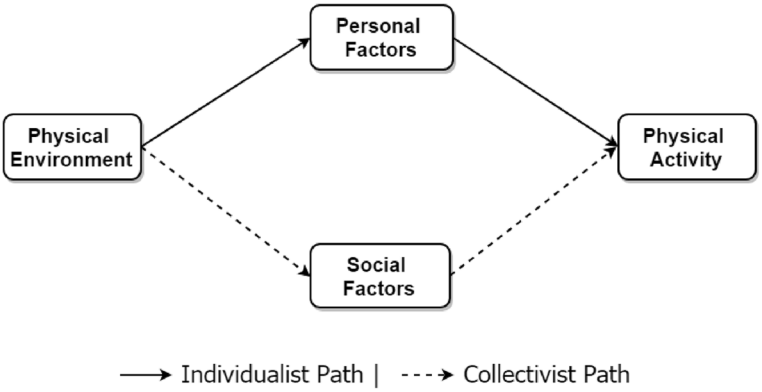

Fig. 4 Abstract model showing the path to engagement in physical activity for the two types of culture

the global model, all of the five determinants (*Social Support*, *Self-Efficacy*, *Physical Environment*, *Self-Regulation* and *Outcome Expectation*) can be implemented in a "one-size-fits-all" persuasive application, with each determinant mapped to one or more persuasive strategies. Most of the persuasive strategies were drawn from Fogg's [12] PT design principles, Oinas-Kukkonen and Harjumaa's [79] Persuasive System Design (PSD) model, Orji and Mandryk's [26] design guidelines for healthy eating behavior, and Yoganathan and Kajanan's [77] SCT-based design principles for successful fitness applications.

However, research [26] has shown that persuasive strategies that are tailored to specific demographics (e.g., culture) are more likely to be effective among the target population. Consequently, we mapped the significant determinants (based on their total effect on *Physical Activity*) in each culture-specific model to their equivalent persuasive strategies in the PT domain. For example, *Self-Efficacy* in the individualist model is mapped to Reduction, Tunneling, etc., in the PT domain. Similarly, *Self-Regulation* is mapped to Self-Monitoring, Goal-Setting, etc. Thus, in a tailored app for the individualist culture, these persuasive strategies are most likely to be effective in motivating behavior change in the physical activity domain. In contrast, *Social Support* in the collectivist model is mapped to socially oriented strategies such as Social Learning, Normative influence, Social Facilitation, Cooperation, etc., in the PT domain. Thus, in a tailored app for the collectivist culture, these persuasive strategies are most likely to be effective in promoting behavior change in the physical activity domain. Moreover, *Social Support* is applicable to the individualist culture as well; however, it is stronger in the collectivist culture than in the individualist culture as the results of our total effect analysis showed. Thus, the higher likelihood of the persuasive strategies operationalizing *Social Support* to be effective in the collectivist culture than in the individualist culture is depicted in Table 5 by bold checkmarks (✓) as opposed to regular checkmarks (✓) in the individualist culture.

6.3 PT General Design Guidelines

In Appendix Table 8, we provided a more detailed set of general guidelines for implementing the key persuasive strategies outlined in Table 5. Though research has shown that persuasive apps will be more effective if personalized, there are certain times when designer of such apps may adopt a one-size-fits-all approach. This can be due to economic reasons [26] or time constraint. For example, a health service provider may be

Table 5 Global and culture-specific mapping of SCT determinants of physical activity to persuasive strategies in the application domain [12, 25, 26, 77, 78]

SCT Construct	PT Strategy	Explanation	GLO	IND	COL
Social Support	Social Learning	Allow users to observe others performing the target behavior and see the outcome.	✓	✓	✓
	Social Comparison	Allow users/groups to compare their performance with that of others.	✓	✓	✓
	Normative Influence	Provide a means for bringing together users with the same characteristics and goals to feel the group norms, appraise and visualize one another's accomplishments.	✓		✓
	Social Facilitation	Provide a means for users to discern when other users are performing the target behavior and their performance.	✓	✓	✓
	Social Role	Provide users with an actual or virtual coach to teach/show how to perform the target behavior and encourage users by providing reminders and feedback on their performance and progress.	✓	✓	✓
	Cooperation	Provide a means for users with the same characteristics, skillsets and goals to cooperate to achieve their target goals.	✓	✓	✓
	Social Recognition	Provide a means for users to be publicly recognized when they accomplish certain tasks/goals and win certain challenge/competition.	✓	✓	✓
	Competition	Provide a means for users/groups to compete with one another towards achieving a given goal or reward.	✓	✓	✓
	Group Customization	Allow one user, in a group-based setting, to tailor on behalf of the other users based on the group preference.	✓		✓
	Reminder	Allow users to be reminded by friends and family members to perform target behavior.	✓	✓	✓
Self-Efficacy	Reduction	Simplify the performance of a difficult/complex task into few simple steps that require less extraneous efforts.	✓	✓	
	Tunneling	Provide a means of guiding user through the performance of the target behavior in a step-by-step fashion (e.g., with the aid of a virtual personal trainer or coach).	✓	✓	
	Self-Monitoring	Allow user to track his/her performance and progress.	✓	✓	
	Reminder	Remind user to perform the target behavior at the opportune moment.	✓	✓	
	Suggestion	Suggest the favorable behaviors to user at the right time and place.	✓	✓	
	Praise	Applaud users for performing the target behavior through the use of words, images, symbols, sound or video as a form of motivational feedback.	✓	✓	

Table 5 (continued)

SCT Construct	PT Strategy	Explanation	GLO	IND	COL
	Reward	Reward user with points, badges, etc,. when s/he performs the target behavior or achieve a certain goal/milestone.	✓	✓	
	Goal-Setting	Allow user to set goals for him/herself	✓	✓	
	Incremental Goal-Setting	Provide user the opportunity to begin with an easily achievable goal and increase gradually.	✓	✓	
	Role Modeling	Allow user to watch similar others with similar attributes (e.g., age, gender, culture, etc.) perform task.	✓	✓	
Physical Environment	Suggestion	Suggest to user nearby recreational facilities to carry out specific physical activities at opportune moments.	✓	✓	✓
		Suggest to user to perform certain physical activities at the right time and place (e.g., taking the staircase rather than the elevator).	✓	✓	✓
		Suggest to user good weather conditions in the future to perform certain outdoor physical activities, e.g., running.	✓	✓	✓
Self-Regulation	Self-Monitoring	Allow user to track his/her performance and status, and be informed about how s/he might modify his/her behaviors to achieve a desired goal or outcome.	✓	✓	
	Goal-Setting	Allow user to set goals for him/herself.	✓	✓	
	Feedback	Provide user with summary feedback on his/her progress in relation to his/her goal.	✓	✓	
	Customization	Allow userto customize his/her user interface to suit his/her preferences.	✓	✓	
	Role Modeling	Allow user to watch similar others with similar attributes (e.g., age, gender, culture, etc.) perform task.	✓	✓	
	Reward	Reward user with points, badges, etc., when s/he performs the target behavior or achieve a certain goal/milestone.	✓	✓	
Outcome Expectation	Simulation	Provide a means for users to observe/establish a link between the cause and effect of their behavior (e.g., by using a virtual coach to imitate the real-world experience and outcome).	✓		✓
	Conditioning	Provide immediate positive reinforcement (e.g., virtual points) to reward the performance of the target behavior.	✓		✓
	Biofeedback	Provide means for user to observe changes in body as a result of performance of target behavior.	✓		✓
	Suggestion	Suggest to user to perform certain physical activities at the right time and place (e.g., taking the staircase rather than the elevator) and the benefit of performing the suggested behavior.	✓		✓

Table 5 (continued)

SCT Construct	PT Strategy	Explanation	GLO	IND	COL
	Social Recognition	Allow users to be publically recognized for the performance of a task or the achievement of a given goal (e.g., receiving a thumbs-up liking in their social network).	✓		✓
	Gain-Framed Appeal	Portray the outcome of the target behavior in terms of what user stands to gain when they perform it.	✓		✓
	Group Endorsement	Provide a means for users to be endorsed by affiliated groups.	✓		✓
	Expert Endorsement	Provide a means for users to be endorsed by recognized experts in the behavioral domain.	✓		✓
	Group Surveillance	Allow the success and failure of one user to result in group-based reward and punishment, respectively.	✓		✓
	Deviation Monitoring	Allow users to be informed about their deviation from the norms, standards and goals of the group.	✓		✓

Note: The checkmark indicates the strength of applicability of persuasive strategy to the identified group

✓ = bold checkmark indicates total effect of construct on physical activity is significantly greater than 0.2 ("strong").

✓ = regular checkmark indicates total effect of construct on physical activity is significant but less than 0.2 ("weak").

Unchecked cell indicates total effect of construct on physical activity that is non-significant in the model.

GLO = global (general) population | IND = individualist population | COL = collectivist population.

interested in rolling out a health app that supports behavior change ahead of its competition. For these reasons, adopting a one-size-fits-all-approach may be unavoidable, at least in the earlier stage of the roll-out of the app. With respect to our total effect analysis (see Fig. 3), operationalizing *Physical Environment* and *Social Support* may be the optimal way to go in a one-size-fits-all persuasive app with limited features. We make this recommendation because both constructs have an overall significant effect on *Physical Activity* in the global as well as the culture-specific models. However, a one-size-fits-all app is less likely to be effective than a tailored app, thus the need for a theory- and evidence-based tailoring to user characteristics. As part of our general design guidelines, where necessary, we specified ways to further tailor the respective persuasive strategies to the different types of cultures (see Appendix Table 8).

6.4 Contributions

Our study makes a number of contributions to the existing body of knowledge with respect to SCT model and PT health interventions in the physical activity domain. Our contributions can be summarized as follows:

1. We presented two SCT models of the physical activity of members of individualist and collectivist cultures and showed how both culture-specific models differ and are similar.
2. We augmented the traditional SCT model with the *Physical Environment* construct by showing its relationships with the other (traditional/core) SCT constructs in the context of culture.
3. We mapped the respective SCT determinants of physical activity in both cultures to corresponding implementable persuasive strategies in the PT domain.
4. We replicated some of the key findings in the existing literature. For example, Orji and Mandryk's [26] found that, in the eating domain, *Self-Efficacy* is the strongest determinant of *Healthy Eating* among members of the individualist culture, which we replicated in the physical activity domain. Similarly, Rovniak et al. [44] found that *Self-Efficacy* and *Self-Regulation* are the strongest determinants of *Physical Activity* among members of the individualist culture, which we also replicated in our study.

6.5 Limitations

There are a number of limitations associated with our study. The first limitation is that the data collection is based on self-report, which may not be as reliable as an objective study such as using technology (e.g., mobile application, pedometer, accelerometer, etc.) to track participants' physical activity over time. We acknowledge that the collected data could be susceptible to memory bias on the part of the subjects, and unintentional human errors on the part of the researchers, especially during the collation of participants' response to the paper-based questionnaire. Both of these limitations could impact the validity of our findings. Moreover, besides cultural differences, we acknowledge that the path coefficients of the different relationships between constructs could be moderated by other demographic factors such as age, gender and national differences, which we did not consider in this paper. However, out of curiosity, we did carry out an MGA on our culture-specific models to gain insight into the moderating

effect of nationality (country of origin) in particular. With respect to the collectivist model, the results of the MGA showed that the Nigerian and Chinese groups are very similar. *Social Support*, as in the overall collectivist model, turned out to be the strongest determinant of *Physical Activity* in both groups. Similarly, with respect to the individualist model, the results of the MGA showed that the individualist group and the collectivist group resident in an individualist country are very similar as well. *Self-Efficacy*, as in the overall individualist model, turned out to be the strongest determinant of *Physical Activity* in both groups. The second limitation of our study is the imbalance between the individualist ($n = 218$) and collectivist ($n = 415$) sample sizes. This has the potential of making path coefficients in the collectivist model being more susceptible to statistical significance than those in the individualist model. Finally, the third limitation of our study is that the collected data for individualist culture, in particular, is based on convenience sample (one Canadian university only). This may limit the generalization of our findings to other individualist student populations. However, given that our findings, overall, underscore the conceptual views of the two different types of culture (individualism and collectivism), the results we have presented can serve as an empirical basis against which future subjective and objective studies can be compared.

7 Conclusion and Future Work

In this paper, we presented an SCT model of the physical activity of members of individualist and collectivist cultures using university students as a case study. Our individualist model accounts for 43% of the variance of *Physical Activity*, with *Self-Efficacy* and *Self-Regulation* being the strongest determinants of the physical activity of members of the individualist culture. On the other hand, our collectivist model accounts for 19% of the variance of *Physical Activity*, with *Social Support* being the strongest determinant of the physical activity of members of the collectivist culture. We mapped the respective SCT determinants of physical activity to relevant persuasive strategies in the PT domain. Thus, in the individualist culture, self-motivating strategies such as Reduction, Tunneling, Self-Monitoring, Goal-Setting, etc., will be most effective in promoting behavior change. However, in the collectivist culture, socially oriented strategies such as Cooperation, Normative Influence, Social Facilitation, etc., will be most effective in promoting behavior change. Moreover, we provided a set of general design guidelines for implementing the various persuasive strategies in the PT domain. In future work, we intend to investigate how other demographic factors such as age, gender and nationality moderate the interrelationships among the constructs in the SCT models. In addition, we aim to use our findings to inform the implementation of a culture-tailored PT intervention and evaluate it with our target audience.

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Compliance with Ethical Standards

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Appendix 1

Table 6 SCT constructs, measurement scales and example indicators

Construct	Measurement scale	Example indicators
Self-Efficacy (SE) [66]	Self-Efficacy (9 items) [Not Confident (0) to Very Confident (10)]	How confident are you right now that you can exercise three times per week for 20 min if: 1) You felt stressed? 2) You had to exercise alone? 3) You were too busy with other activities?
Self-Regulation (SR) [44]	Exercise Goal Setting (10 items) Exercise Planning (10 items) [Does Not Describe Me (1) to Describe Me Completely (5)]	1) I often set exercise goals. 2) I never seem to have enough time to exercise. 3) I schedule all events in my life around my exercise routine.
Outcome Expectation (OE) [65]	Physical OE (5 items) Social OE (3 items) Self-Evaluative OE (4 items) [Strongly Disagree (1) to Strongly Agree (5)]	1) Exercise will strengthen my bones. 2) Exercise will improve my social standing. 3) Exercise will give me a sense of personal accomplishment. 4) Exercise will help manage stress.
Social Support (SS) [64]	Family SS (5 items) Friends SS (5 items) [None (1) to Very Often (5)]	1) During the past 3 months, my family offered to exercise with me. 2) During the past 3 months, my friend(s) gave me helpful reminders. 3) During the past 3 months, my friend(s) gave me encouragement to stick to my exercise program.
Physical Environment (ENV) [67]	Environment (10 items) [Strongly Disagree (1) to Strongly Agree (4)]	1) I have access to exercise and sports equipment at home e.g., weights, racquets, skis for personal use. 2) My school provides facilities to support me walking or cycling to work/school, e.g., changing rooms, bike storage. 3) There is an open recreation area (e.g., park, beach or other open space) within easy walking distance of my home.
Physical Activity (PA) [68]	Physical Activity (3 items) [Numerical scale containing vigorous-, moderate- and light-intensity activities]	1) During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling? 2) How much time did you usually spend doing vigorous physical activities on one of those days?

Appendix 2

Table 7 SCT Constructs' items dropped from the respective measurement models due to poor loading

Construct	Indicators dropped from the respective SCT models	GLO	COL	IND
Self-Efficacy (SE)	1) How confident are you right now that you can exercise three (3) times per week for twenty (20) minutes if you felt tired?		✓	
Self-Regulation (SR)	1) Exercise is generally not a high priority when I plan my schedule.	✓	✓	
	2) I never seem to have enough time to exercise.	✓	✓	
	3) Finding time for exercise is difficult for me.	✓	✓	
	4) When I am very busy, I do not do much exercise.	✓	✓	
	5) I schedule all events in my life around my exercise routine.		✓	
Physical Environment (ENV)	1) Most of the houses in my neighborhood are detached houses.	✓	✓	
	2) Walking and cycling are unsafe because of the traffic in my neighborhood.	✓	✓	
	3) Walking and cycling are unsafe because of the level of crime in my neighborhood	✓	✓	
	4) Many shops, stores, markets or other places to buy things I need are within easy walking distance of my home.			✓
	5) There is a transit stop (such as bus stop, train, trolley or tram station) within easy walking distance of my home.			✓
	6) There are many different routes for cycling or walking from place to place in my neighborhood so I do not have to go the same way every time.			✓

Note: GLO = Global Model, COL = Collectivist Model, IND = Individualist Model; ✓ indicates a removed item from a given construct

Appendix 3

Table 8 General design guidelines for implementing SCT-based persuasive strategies in the physical activity domain

Guideline #1: Break a complex (hard) activity into simpler steps to facilitate its performance [*Reduction*].

Break a complex activity into a simpler one (or fewer steps). This has the potential of making the user develop and approach the target behavior with a more positive attitude and a firmer belief in his/her ability to carry out the activity. Specifically, the Reduction strategy is suited to members of individualist cultures as a result of their tendency to be self-reliant and goal-oriented [80]. An example of the Reduction strategy in a persuasive app is the modification of the conventional floor-based push-up to a chair-based push-up for elderly people and beginners.

Guideline #2: Guide or walk the user systematically through the performance of the target activity to reduce uncertainty and/or difficulty [*Tunneling*].

Guide the user through a predetermined sequence of actions in a step-by-step fashion to increase his/her self-efficacy and motivation. A virtual coach in a persuasive app could be used to achieve this. A typical example of Tunneling for push-up exercise behavior includes: (1) *Get into the push-up position, with arms fully extended*; (2) *Lower yourself until your elbows are bent at 90°*; and (3) *Return to the starting position*. This strategy is suited to members of the individualist culture, who would prefer to work out alone [15, 80].

Guideline #3: Allow the user to observe a similar other or model perform the behavior [*Role Modeling*].

Allow the user to watch a similar other (real or virtual) perform the target behavior. This has the potential of increasing the user's self-efficacy and motivation to perform the target behavior [81–83]. Role models can serve as a social mirror for the user to visualize success scenarios as well as provide positive guides and supports for performance [37]. According to [81], a role model embodies the goal of the user. As a result, "*the power of role models can be harnessed to increase role aspirants' motivation, reinforce their existing goals, and facilitate their adoption of new goals*" (p. 465). In a prior study [84] that investigated the effectiveness of using video-based Role Modeling to increase self-efficacy for exercise tolerance (peak oxygen uptake), it was found that the self-efficacy of the intervention group was higher than that of the control group.

Guideline #4: Allow user to record or track his/her physical activities and outcomes [*Self-Monitoring*].

Allow the user to keep track of his/her activities, the context in which they occur, their outcomes and the immediate and long-term effects. Examples of trackable activities include steps (e.g., count, distance, etc.), push-up or weight-lifting (e.g., repetitions, duration, etc.), while examples of outcomes include weight loss, calorie burned, etc. As one of the most dominant strategies used in health promotion applications [14], self-monitoring has to be truthful, consistent and timely to be effective [85]. The Self-Monitoring strategy is more likely to be effective in the individualist culture than in the collectivist culture due to the independence and self-motivation of the former [80].

Guideline #5: Allow the user to set goals and reward their achievement [*Goal-Setting* and *Reward*].

Allow the user to set goals and timeframes within which they will be achieved and reward their achievement. According to [86], goals influence performance through four mechanisms: (1) *serve as a directive function*: goals direct the attention and effort of people towards goal-based activities and away from non-goal-based activities; (2) *provide an energizing function*: the effort put in achieving goals is proportional to the level of set goal, i.e., the higher the goal, the higher the effort; (3) *affect persistence*: the harder the goal the more prolonged the effort put in if people are allowed to control spent time on a task; besides, the harder the goal, the more likely people are going to work harder and faster, with tight deadlines resulting in more rapid work than loose deadlines; and (4) *affect action indirectly*: goals lead to arousal, discovery and leveraging of task-relevant knowledge and strategies. As cited in [87], the commitment of the user to his/her goals is the strongest driver of behaviors. Moreover, goals are more likely to be achieved if commitment to them are made public and their attainment are rewarded [87]. Moreover, research [79, 87] has shown that rewarding achieved goals encourages the performance of the target behavior. The Goal-Setting strategy is more suited to the individualist culture than the collectivist culture [80].

Table 8 (continued)

Guideline #6: Allow the user to receive feedback on the performance of the target behavior [*Feedback*].
Provide the user with feedback on his/her performance and progress. This can be achieved by providing the user with summary feedback that reveals his/her progress in relation to his/her goals. This is important because if the user does not know how s/he is doing, it may be difficult, and even impossible, for him/her to make the necessary adjustment to the level or direction of his/her effort. It may also be difficult for him/her to adjust his/her performance strategies to match the requirements of his/her goal. As a result, allowing the user to know where s/he is at will help him/her to regulate him/herself accordingly. For example, when people find themselves lagging behind in the completion of a task or below target, they tend to double their efforts or increase their working speed to realize their goal in due time [86]. Moreover, summary feedback can moderate the effectiveness of goals. For example, the combination of goals with feedback is likely to be more effective than just goals alone [86]. The Feedback strategy is more suited to the individualist culture than the collectivist culture [14, 80].

Guideline #7: Allow the user to customize his/her application [*Customization*].
Allow the user to tailor the application to suit his/her personal preferences. This can be implemented by allowing the user, for example, to decide the look and feel of his/her user interface, what and how information on the performance of the target behavior should be displayed on their user interface, what information about their behavior should be made public or not, what features (e.g., persuasive strategies) should be activated or deactivated, what avatar should be used in the app, etc. According to [77], allowing users to customize information relating to their personal needs, interests, emotions and contexts would enable them to be pay more attention to the information and process it more carefully, which will eventually help them to formulate goals that are suited to them. While, for the individualist culture, customization can be implemented on an individual basis, for the collectivist culture, it can be group-based. Collectivists have been known to possess fewer well-defined 'personalities' than individualists, with their behaviors being heavily dependent on the context, actions, and attitudes of their in-group as a whole [25].

Guideline #8: Provide the user with an opportunity to cooperate with other users of the app [*Cooperation*].
Provide the user with an opportunity to collaborate with other users of the app in the performance of the target behavior. For example, users can be allowed to work together in pairs, groups or teams to set and achieve a collective goal. This form of social support is more likely to be effective in the collective culture given the natural tendency of collectivists to be interdependent and put the interests of their in-groups before personal interests. As seen in the collectivist model, *Social Support* (receiving actual support and/or encouragement from friends and family members) emerges as the strongest driver of physical activity. Thus, collectivist users should be allowed to support one another through cooperation and working with one another to achieve collective goals. For example, two or three users can team up to set and achieve a collective goal, e.g., 20,000 or 30,000 steps a day, with each member of the group expected to realize 10,000 steps.

Guideline #9: Allow the user to be able to observe other users performing the behavior [*Social Learning*].
Provide the user with the means to watch other users performing the target behavior together with the outcome [39]. For example, the achievement of a daily physical activity goal (e.g., 10,000 steps, 500 push-ups, etc.) by one user (User A) can be shown to another user (User B) with similar characteristics (e.g., skillsets) with the intention of motivating User B to perform the target behavior. Moreover, users can be allowed to upload the performance of the behavior (e.g., a video of a push-up session), if possible, as evidence of the achieved goal. Both the performance of the behavior and the achieved goal, in a social context, have the potential of motivating similar others to perform the target behavior and/or achieve the target goal. The Social Learning strategy would be more effective in the collectivist culture if its implementation is group-based, e.g., users are allowed to cooperate, to achieve a collective goal. In that case, given the natural tendency of collectivists to fit in with their in-groups [25], allowing the target user to observe multiple other users in his/her in-group, who have performed the target behavior, has the potential of pressuring him/her to conform, as s/he may not want to be responsible for the group's failure to achieve its goals.

Guideline #10: Provide the user with an opportunity to compare his/her performance and achievements with those of other users [*Social Comparison*].
Allow the user to be able to compare his/her performance of the target behavior as well as achieved goals with those of other users of the app. In the context of PT, this can be achieved using a leaderboard [88]. While the

Table 8 (continued)

Social Comparison strategy in the individualist culture can be implemented on an individual basis, in the collectivist culture, it should be group-based rather than individual-based, with each group cooperating to achieve a collective goal set by the group. This is based on Hofstede's [29, 30] finding that individuals in collectivist cultures mainly work together for a common interest and the greater good. Thus, given that, in the collectivist culture, the deviation from or violation of the norms results in a feeling of shame [29], in the context of a group-based competition on a leaderboard, members of each user-group may be pressured to carry out their individual assignment or task so that the group as a whole can achieve the collective goal set for itself in the long run [25].

Guideline #11: Allow the user to observe and feel the norms of the in-group s/he belongs to facilitate compliance [*Normative Influence*].

Provide a means for users to be grouped together and feel the group's norms, appraise and visualize one another's accomplishment of the target behavior [79]. Normative Influence (the influence which other people have on a person) can lead the user to conform, for example, just to be accepted and liked in the in-group. However, though Normative Influence can lead to the user's public compliance with the behaviors of the group, it may not necessarily lead to private acceptance of them [89]. Given that members of the collectivist culture are liable to conform to the norms of their in-group, otherwise they will feel socially isolated, this strategy is more likely to be effective in this culture than the individualist culture.

Guideline #12: Allow users to discern the behavior and performance of other users [*Social Facilitation*].

Providing users with the means to discern when other users are performing the target behavior as well as observe their level of performance. The principle of Social Facilitation holds that people tend to perform better when in the presence of others [79, 90]. This strategy, which is similar to Social Facilitation, will be more effective in the collectivist culture than in the individualist culture given its social features. For example, in a collaborative setting, given the tendency of collectivists to feel safety in number and accountable [91], it is more likely that members of the group will be motivated to perform the target behavior when they see other members performing the target behavior compared to otherwise.

Guideline #13: Allow the user to be recognized by other users for his/her achievements [*Social Recognition*].

Provide a means for the user's achievements to be publicly acknowledged and rewarded by other users. This can be implemented with the aid of likes, badges, medals, stars, etc. According to [92], Social Recognition is more likely be effective if it is used in a small and closed group of users where all of the users virtually know each other, as most users prefer to be socially recognized among the people they are familiar with. Thus, this strategy may be more effective in the collectivist culture. A recent study [93] of a social system showed that Middle Eastern participants (collectivists) are more likely to provide feedback if they are socially recognized than United Kingdom participants (individualists). In addition, they found that socially recognized Middle Eastern participants will feel more socially constrained to improve their social behavior as they know their behavior henceforth is under the spotlight of the community of people who now know them. Moreover, users can be recognized collectively on achievement of a group-based goal, especially in a collectivist culture.

Guideline #14: Allow the user to compete with other users [*Competition*].

Allow the user to compete with other users on the achievement of similar goals. Competition, which is the natural drive in humans to outperform one another, has the potential of motivating people intrinsically [88]. In persuasive systems, this can be implemented by allowing users to compete with one another or the system. In the individualist culture, individual-based competition will be more effective [91]. It could be against others or the system. However, in the collectivist culture, given the natural tendency of members to conform and work together to achieve collective goals, coupled with the fact that individuals are discouraged from standing out, group-based competition is more likely to be effective than individual-based competition [93, 94].

Guideline #15: Allow the user to observe the cause and effect of the target behavior [*Simulation*].

Provide a means for the user to observe and establish a link between the cause and effect of their behavior. Research [12] has shown that persuasive applications can persuade people to change their behavior if they can allow people to observe a link between the immediate cause and effect of their behaviors. According to [14], given that the practice of healthy behavior is a lifestyle that spans over a lifetime, and thus may not

Table 8 (continued)

have immediately visible consequences, people tend to be discouraged from adopting healthy behaviors that do not have observable immediate benefits or outcomes. Thus, using the simulation strategy for health behaviors with long-term consequences may help address this problem, as users will now be able to visualize their behaviors and compare outcomes of alternative behaviors over a given period of time [14].

Guideline #16: Allow the user to be rewarded for their achievements [*Conditioning and Reward*].

Allow the user to be rewarded for completing his/her goal by the system. Conditioning can be used to operationalize *Outcome Expectation* owing to the fact people anticipate the consequences of their behavior (health- or non-health-related) prior to engaging in it [38]. Conditioning is the use of positive reinforcement to increase the chances of repeating a behavior [12]. It uses the principle of operand conditioning [95]. According to [55], people are more likely to repeat a given behavior if it is rewarded (positive reinforcement). Given that it is difficult to visualize the short-term benefits of most health behaviors, Reward, in the meantime, tends to provide an immediate reinforcement and present the user with something (e.g., virtual points, levels, badges, etc.) to work for [96, 97].

Guideline #17: Allow the user to be suggested favorable behaviors at the opportune moment [*Suggestion*].

Provide a means for the user's app to intervene at the right time and place by suggesting beneficial physical activities [14]. Typical examples of beneficial suggestions include using the elevator rather than the stairs by a context-aware mobile app; standing up, stretching or walking around after a long computer-screen time by a desktop app; etc. The Suggestion strategy is more likely to be effective in collectivist cultures than in individualist cultures due to the fact that collectivists are "*more accustomed to relying on the opinions and suggestions of other in-group members, or looking to social norms to decide their actions*" (p. 61) [15]. According to [15], using the computer as a social actor [12, 98] of behavior change among collectivists may prevent people from suffering public loss of face, which is the characteristic risk of making behavioral suggestions to group members in collectivist cultures.

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