



# Personalizing mHealth Persuasive Interventions for Physical Activity: The Impact of Personality on the Determinants of Physical Activity

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**Abstract.** Behaviour changes and persuasive mobile health (mHealth) technologies have shown success in motivating people to be more active and engage in physical activity. Research has demonstrated that persuasive interventions perform better if they are theory-driven and personalized. Thus, various research has addressed personalizing mHealth technologies based on different aspects. However, the literature lacks studies on the moderating effect of personality traits on the determinants of physical activity as identified by the Health Belief Model. To fill this gap, we conducted a large-scale study of 430 participants' physical activity behaviour, associated determinants, and individuals' personality traits. We developed a general model showing how the determinants impact physical activity and a personality-based model exploring the moderating effect of personality. Then, we explored the differences between the two models, as well as between distinct personalities within the personality-based model. Our findings show that people of distinct personalities respond differently to the behaviour change determinants. Based on the results, the paper provides recommendations for designing personalized persuasive mHealth interventions for promoting physical activity.

**Keywords:** Mobile Health · Physical Activity · Personality Traits · Health Belief Model (HBM) · Persuasive Technology

## 1 Introduction

Being physically inactive is a cause of many health diseases, including diabetes [26], obesity [29], and cardiovascular [47]. Besides, researchers have found that regular physical activities are strongly associated with a reduced risk for severe COVID-19 outcomes [41]. Many health authorities have recommended adults engage in at least 150 min/week of moderate to vigorous physical activity (MVPA) [36]. Many countries have promoted this recommendation based on solid evidence that regular physical behaviour results in a broad range of health benefits [41]. However, many people do not have the motivation to engage in regular physical activity. Thus, several persuasive interventions have been proposed to increase individuals' likelihood of being more physically active.

Software systems designed to change individuals' behaviour are called Persuasive Technologies (PT) [10]. Persuasive technologies have been used extensively in several behaviour change domains, including physical activity. Furthermore, it has become a consensus in the literature that a one-size-fits-all approach is insufficient, and the persuasive interventions should be tailored to different users' groups. Thus, several studies have discussed this issue and proposed potential solutions to personalize PT based on various theories and models. Among these models is the Health Belief Model (HBM) [39], which is developed to explain why people may or may not take action to prevent diseases or activities that cause health issues. It states that the likelihood that an individual will engage in a health-related behaviour is influenced by six determinants: Perceived Susceptibility, Perceived Severity, Perceived Benefit, Perceived Barrier, Cue to Action, and Self-efficacy. The HBM is one of the most widely applied health behaviour theories [14, 25, 32, 33]. Over several years, the HBM has been used to predict factors that affect people's behaviours, such as eating habits and physical activity and inform behaviour change intervention design. Therefore, researchers have used this model to tailor persuasive interventions based on different factors, such as age, gender, and culture.

The literature has suggested that tailoring persuasive interventions based on users' personalities is an effective approach to enhance the performance of these interventions [17]. This suggestion has been demonstrated in the health domain as well as other fields, such as games [4, 34] and eCommerce [2]. Nonetheless, there is a dearth of research on whether personality moderates the impact of the HBM's determinants on people's behaviour. This is essential for designing theory-driven interventions that are tailored to be appropriate for each individual depending on their personality type. This paper aims to fill this gap by exploring the impact of personality traits on the HBM behaviour change determinants. It also shows how to tailor persuasive mobile interventions to various personalities. The research is guided by two overarching research questions: (1) How does the impact of the HBM's behaviours determinants of physical activity vary across Personality Traits? (2) How can mobile persuasive interventions for promoting physical activity be tailored to individuals who are high in distinct personalities?

To answer this research question, we conducted a large-scale study of 430 participants. Following the recommendation of a previous study [1], we employed the six determinants of the HBM model along with a seventh determinant (namely, the Social Influence), which has been shown to be a strong determinant of physical activity. To distinguish participants' personalities, we employed the Big Five-Factor model (FFM) [30]. The FFM categorizes people's personalities based on five broad factors (or traits): Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism.

Data were collected through a survey study that involved three parts: participants' demographics, perception of the HBM determinants, and personality test. Using our data, we developed two models: a general model showing how the determinants impact physical activity and a personality-based model exploring the moderating effect of personality traits. Then, we explored the differences between the two models, as well as between distinct personalities within the personality-based model. Our findings show that people who are high in distinct personalities respond differently to the behaviour change determinants. Our findings reveal that the relation between the determinants and physical activity behaviour varies based on an individual's personality. For example, people

who are high in Openness are mostly influenced by Perceived Benefit and Self-Efficacy, while Conscientiousness can be motivated by Self-efficacy and Social Influence, but Perceived Barrier demotivates them. People high in Extraversion emerged as the most influenced personality, with five determinants being significantly related to them. In contrast, Agreeableness and Neuroticism emerged as the least influenced personalities with no significant positive relationship with any determinants. Based on our findings and extensive examination of the literature, we map the determinants to their corresponding persuasive strategies for operationalizing them and provide recommendations for designing persuasive interventions tailored to different personalities. To the best of our knowledge, this study is the first to examine the relationship between health behaviour change determinants (identified by the HBM) and personality traits (identified by the FFM) to develop guidelines for tailoring persuasive interventions to promote physical activity.

The contributions of this work can be summarized as follows: 1) It applies the HBM to conduct a comparative investigation of the determinant of physical activity. 2) It investigates the moderating effect of personality traits on the HBM determinants of physical activity. And 3) It maps the HBM determinants to the personality traits and provides recommendations for designing persuasive systems that are personalized based on the big five personality traits and informed by the HBM determinants.

## 2 Background

Several studies have demonstrated that designing persuasive interventions based on well-established theories enhances these interventions and makes them more successful [7, 31, 40]. These theories help understand health behaviours, which, in turn, help in tailoring persuasive interventions based on behaviour change determinants [35]. This section presents an overview of the main concepts used in this work, the Five-Factor Model of personality and the Health Belief Model. This is followed by a review of persuasive interventions for behaviour change, with a focus on works related to the HBM and physical activity.

**Five-Factor Model (FFM) of Personality.** Humans are different in their characteristics. The extensive research about human behaviours has led to introducing several theories about human personality. Among these theories, the Five-Factor Model (FFM) [44] is the most widely accepted personality theory. It highlights a set of five factors, known as the Big-five personalities. These personalities are Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. These five personality traits cover a wide range of personalities, and they are known by their relative stability throughout individuals' lives. Each of the five factors is described by many characteristics [30].

Personality is hypothesized to affect habits and behaviours [38]. Researchers have studied the impact of personality on individuals' physical activity. For instance, Chan et al. [5] examined the interactions of leisure-time, physical activity and personality traits on wellbeing, and whether such interactions vary between older adults in Hong Kong (HK) and older adults in the United Kingdom (UK). Based on the analysis of data obtained from 349 participants, the authors concluded that "personality needs to be considered when promoting and providing physical activity for older adults, although more

research is needed to further explore how this can work effectively". Gacek et al. [11] investigated the personality-based determinants of physical activity. The study targeted Polish and Spanish physical education students. 219 Polish and 280 Spanish students participated in the study. The International Physical Activity Questionnaire (IPAQ) [43] was used in the study. The results revealed difference between personality traits. For instance, the level of total, vigorous, and moderate physical activity increased along with the increase in extraversion, while a decrease occurred along with the increase in neuroticism.

**Health Belief Model (HBM).** One of the oldest and most widely employed models of health behaviour promotion [32]. It is designed to predict and explain health-related behaviours. Specifically, HBM explains why people may (or may not) engage in health-related behaviours. It postulates that the likelihood that an individual will participate in health-related behaviour is influenced by six constructs (or determinants) [32], as follows: 1) *Perceived susceptibility*: assessment of the perceived risk for developing a health condition of concern. 2) *Perceived Severity*: individual's assessment of the consequence of contracting the health condition of concern. 3) *Perceived benefit*: individual's perception of the good things that could happen from undertaking specific behaviours. 4) *Perceived barrier*: perception of the obstacles and cost of behaviour change. 5) *Cue to action*: exposure to factors that prompt action. 6) *Self-efficacy*: individuals' confidence in their competence to perform the new health behaviour.

The HBM model has shown to be successful in designing several persuasive interventions for health behaviour change, particularly physical activity [14]. For instance, Jalilian et al. [19] studied the factors related to regular physical activity among Iranian medical college students based on the HBM. A study by King et al. [25] examined the impact of HBM on physical activity for college students. Specifically, the study examines whether college students' perceived benefits, barriers, cues, and vigorous physical activity involvement differed significantly based on several factors, including gender, grade level, parental encouragement, and peer encouragement.

Another study by Hoseini et al. [18] investigated the effect of an education plan based on the health belief model on the physical activity of females at risk of hypertension. The study's findings showed a significant increase in the physical activity levels two months after the intervention, confirming the efficiency of the HBM on the physical activity of women at risk for hypertension. A large-scale study was conducted by Orji et al. [33] to understand how health behaviour relates to gamers type. The study investigates gamers' eating habits and their HBM determinants of healthy behaviour. Based on the results and the differences between the models, the study proposed two approaches (general and personalized approaches) for effective persuasive game design.

A more recent study by Almutari and Orji [1] investigates the determinants of physical activity in collectivist cultures using Saudi Arabia as a case study. In addition, the study investigates the moderating effect of age and gender on the impact of the determinants. The study found that Perceived Severity, Cue to Action and Social Influence are the strongest determinants of physical activity in Saudi adults.

The HBM determinants have also been operationalized in several behaviour change apps. For instance, Lue et al. [27] deployed Cue to Action in a break prompting system (called Time for Break). The app enables people to set their desired work duration and

prompts them to stand up or move. The app implemented cue to action through periodic notifications adjustable via personalized settings to allow people to set up their preferred work and break duration.

Hatami et al. [16] studied the impact of HBM-based educational resources on nutritional behaviour for cancer prevention. The study found that Self-efficacy, Severity, and Benefits were perceived to have a higher impact. It concluded that education plans based on HBM and implemented through multimedia could change nutritional beliefs and behaviours to prevent colorectal cancer.

The HBM model has also been introduced to more recent studies that concern behaviours related to the recently emerged COVID-19 corona virus. For instance, Jose et al. [20] used the HBM determinants to investigate and understand people's perception and preparedness towards the pandemic. Another study by Mahindaratne [28] adopted the HBM to identify factors that affect prevention behaviour against COVID-19. The study revealed that Perceived Benefits and Self-efficacy had a significant positive impact, while Perceived Barriers had a significant negative impact. Accordingly, the study reinstates the usability of the HBM in exploring health behaviour.

These studies and others have shown the effectiveness of the HBM model on predicting factors that influence several health behaviours, including physical activity and informing intervention design. However, there is hardly any research investigating the moderating effect of personality on the impact of these determinants, especially in the area of physical activity. This paper aims to fill this gap by studying the moderating effect of the big five personalities on the impact of the HBM determinants on physical activity.

### 3 Study Design

Our study follows a quantitative research approach. To acquire the data needed for our study, we conducted a survey that assessed the impact of the determinants of HBM along with the Social Influence factor. This section discusses the study design regarding instruments used to evaluate the determinants and the personality test, participants, and data analysis.

#### 3.1 Measurement Instrument

We conducted a large-scale survey to study the relationship between determinants that motivate physical activity and personality traits. The survey was developed after an extensive literature review of behaviour change theories, personality traits, physical activity behaviour motivators, and persuasive technology interventions for physical activity. The survey was also pilot tested on 15 participants for refinement. It is worth mentioning that this study was approved by the Research Ethics Board at the University. This survey instrument consists of three sections: participants' demographics, the behaviour change determinants, and personality assessment.

In the demographic section, we asked participants about age, gender, and education level. In the second section (behaviour change determinants), we relied on the six determinants of the HBM and the Social Influence. The HBM is used because the literature

shows that HBM is a helpful framework for designing both long and short-term behaviour change interventions [13]. Also, it has been successfully adapted and deployed in many persuasive interventions for health [22, 45]. Based on the recommendations and the findings of previous studies [1], we also added Social Influence as a seventh determinant. This part of the survey involves seven sections: one for each determinant. A 7-point Likert scale ranging from “1 = Strongly disagree” to “7 = Strongly agree” was used for each question. All the survey questions were adapted from previous research where they were validated [9, 14, 21, 32, 35]. These HBM determinants questions include 1) eighteen questions measuring Perceived Benefits – e.g., being physically active most of the time would be beneficial to me; 2) fourteen questions measuring Perceived Barriers – e.g., A major barrier to physical activity for me is cost; 3) two questions measuring Perceived Susceptibility – e.g., If I do not stick to regular exercise, I will be at high risk for some physical inactivity related diseases; 4) three questions measuring Perceived Severity – e.g., The thought of ending up in the hospital due to physical inactivity related diseases scares me; 5) fourteen questions measuring Cue to Action – e.g., I am motivated to exercise if I gain weight and not fit in my clothing; 6) six questions measuring Self-efficacy – e.g., If I want, I could easily exercise within the next two weeks; and 7) four questions measuring Social Influence – e.g., I will be more physically active if my friend goes to the gym regularly. More sample questions are provided in the appendix.

In regards to the personality test, we used the 10-item personality inventory (BFI-10), a validated instrument for personality traits evaluation that has been widely employed [37]. The ten items are evaluated in a five-point Likert scale ranging from “1: Strongly disagree” to “5: Strongly agree”.

### 3.2 Participants

Before starting the recruitment process, the research was approved by the ethics board at Dalhousie University. This ethics approval confirm the protection of participants privacy and information confidentiality. We recruited participants through universities email lists and posters published to the public on social media, such as Facebook and Twitter. All participants participated voluntarily, and no compensation was given to them. Information confidentiality we received a total of 442 responses, of which 12 were excluded due to incompleteness and wrong response to the attention determining questions. Among these participants, 264 are female, 164 are males, and two are not specified. Their ages range from 18 to 65.

### 3.3 Data Analysis

The data analysis was done using SmartPLS, a software for structural equation modelling (SEM) using the partial least squares (PLS) path modelling method [48]. SmartPLS is robust and efficient for analyzing complex relationships such as the one investigated in this paper. It has been used extensively by previous research and shown to be effective [1, 23, 32, 42].

In order to confirm that the collected data fits the model (i.e., whether the data replicates the seven determinants in physical activity behaviour), we conducted a component-based Confirmatory Factor Analysis (CFA) [8] using SmartPLS 3. Each indicator (question) loaded onto its corresponding factors. We retained only indicators that had factor loadings of at least 0.5 in the data [15]. In the next step, we used Partial Least Squares (PLS) Structural Equation Modeling (SEM) to establish the relationship between the seven determinants and the physical activity behaviour of different personalities. To do so, we developed a model showing the relationship between personality, the HBM determinants, and the likelihood of physical activity behaviour. Figure 1 shows the model structure.

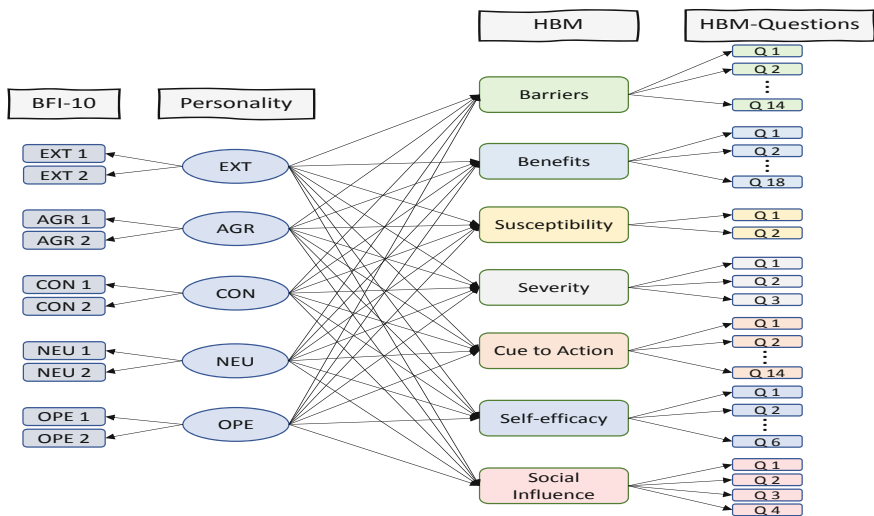


Fig. 1. PLS-SEM model structure

### 3.4 Measurement Validity and Reliability

Data reliability and validity were checked following the same approach implemented by previous research [1, 32, 34]. Specifically, data reliability was assessed using Cronbach's alpha and composite reliability scores. These measures show the strength of the correlation between indicators and their variables [32]. The results show that the indicators are reliable because Cronbach's alpha and composite reliability scores are higher than the threshold of 0.7 [6, 12]. Regarding data validity, it was checked using both convergent and discriminate validity. Data validity and reliability were satisfied for all the required criteria for the PLS-SEM. All constructs have an AVE (the Average Variance Extracted by the variables from its indicator items) above the recommended threshold of 0.5 [6]. The heterotrait-monotrait ratios of correlations (HTMT) were all below the recommended limit of 0.9.

## 4 Results

This section presents the results of our study, and it provides a discussion about our findings. The results are presented based on structural models, which determine the relationship between the determinants (susceptibility, Severity, Benefit, barrier, cue to action, self-efficacy, and Social Influence) and the behaviour. In particular, we have two structural models: one for the whole sample without considering the impact of personality (called the general model) and one showing the moderating effect of personality traits (we called it the personality-based model). In structural models, there are two important criteria; the level of the path coefficient ( $\beta$ ) and the significance of the path coefficient ( $p$ ) [15], where path coefficients measure the influence of a variable on another.

### 4.1 The General Model

This section discusses the relation between the HBM determinants and the likelihood of physical activity for the whole sample without considering the impact of personality. The results presented in Table 1 show that Cue to Action, Social Influence, Self-efficacy, and Perceived Severity emerged as significant motivators of physical activity. Specifically, Cue to Action emerged as the strongest determinant of physical activity behaviour overall. This is followed by Social Influence and Self-efficacy in the second and third place and Perceived Severity in the fourth place. On the other hand, Perceived Barrier emerged as the only determinant negatively associated with physical activity behaviour for the general model. This means that emphasizing this determinant in intervention design may demotivate people from engaging in physical activity behaviours. Finally, Perceived Benefit and Perceived susceptibility have no significant effect on people’s physical activity behaviour.

**Table 1.** Standardized path coefficients and Significance of the general model (whole sample). The numbers represent significant coefficients at  $p < .05$ , and dash (-) represents non-significant coefficients.

BAR	BEN	CUA	EFF	SEV	SUS	SI
-0.19	-	0.25	0.21	0.11	-	0.22

BAR: perceived barrier, BEN: perceived benefit, CUA: cue to action, EFF: self-efficacy, SEV: perceived Severity, SUS: perceived susceptibility, SI: social influence

These results demonstrate the impact of each determinant on the whole sample. As mentioned above, it has been well established that the HBM determinants can predict factors influencing health behaviours without considering the impact of personality. The question that arises here, however, how generalizable are these results? For instance, can we conclude from Table 1 that Perceived barriers, benefits, and susceptibility should not be employed for promoting physical activity for all user types? The literature has shown that determinants’ influence level can be moderated by several factors, including culture, age, gender, and gamer types [1, 32, 33]. We hypothesize that personality could

moderate the extent to which the determinants influence physical activity behaviour. This hypothesis was motivated by the fact that personality has been shown to influence many aspects of people's lives, their beliefs, how to use technology, and their worldview [2, 3, 24, 34]. Nonetheless, there is hardly any research on the possible moderating effect of personality on the impact of the HBM determinants, especially in the area of physical activity. The next section shows how personality traits moderate the impact of the HBM determinants.

## 4.2 Moderating Effect of Personality Traits

This section discusses the relationship between personality traits and the HBM determinant. To achieve the research objective, we developed a model showing the relationship between personality, the HBM determinants, and the likelihood of physical activity behaviour, see Fig. 1. The individual path coefficients obtained from the model are summarized in Table 2. The numbers presented in the table show the level of path coefficients that are significant ( $p < 0.05$ ), while the dashes (-) represent non-significant coefficients. Again, personality is a type scale, hence an individual cannot be classified as belonging to a single personality rather they could be high in one personality trait and low in others. Hence, we simultaneously modeled the relationship between personality traits and HBM factors as shown in Fig. 1. Accordingly, whenever we mention personality traits, we mean people who are high in the corresponding trait. For instance, mentioning "Openness people" indicates people who are high in openness facets according to the personality test (BFI-10).

Table 2 shows that the five personality traits are different with respect to how the HBM determinants impact their physical activity behaviours. People who are high in Openness are positively related to Perceived Benefits and Self-Efficacy, while Conscientiousness people are positively associated with Self-efficacy and Social Influence and negatively related to Perceived Barrier. Extraversion emerged as the most influenced personality; it is positively associated with five determinants (Perceived Benefit, Cue to Action, Perceived Severity, Perceived Susceptibility, and Social Influence). On the other hand, Agreeableness and Neuroticism emerged as the least susceptible personalities as the results did not show any significant positive association between them and the HBM determinants. However, Self-efficacy and Social Influence are negatively associated with Neuroticism.

By comparing the results of the general model (Table 1) with the personality-based model (Table 2), we notice how personality traits moderate the influence of the seven determinants. For instance, the general model shows that both Perceived Benefit and Perceived Susceptibility are non-significant motivators for the whole sample. However, the personality-based model shows that Perceived Benefits emerged as a significant motivator for Openness and Extraversion, while Perceived Susceptibility is a significant motivator for Extraversion. Also, the general model suggests that Social Influence and Self-efficacy are associated positively with physical activity behaviour. Although this is true for Conscientiousness and Extraversion, this is not the case for the other personalities. Particularly, Neuroticism is negatively associated with Social Influence and Self-efficacy. Besides, the general model shows that a total of four determinants (Cue

**Table 2.** Standardized path coefficients and significance for each Personality Trait. Dash (-) represents non-significant coefficients.

Factors	BAR	BEN	CUA	EFF	SEV	SUS	SI
Openness	-	0.14	-	0.12	-	-	-
Conscientiousness	(-0.35)	-	-	0.21	-	-	0.13
Extraversion	-	0.25	0.28	-	0.15	0.26	0.11
Agreeableness	-	-	-	-	-	-	-
Neuroticism	-	-	-	(-0.10)	-	-	(-0.10)

to Action, Self-efficacy, Perceived Severity, and Social Influence) are significantly associated with physical activity behaviour. However, the personality-based model revealed that the personalities perceive these determinants differently. For instance, Cue to Action (which emerged as the strongest determinant in the general model) is a strong determinant only for Extraversion, likewise Severity.

These results show that personality moderates the influence of the HBM determinants on physical activity behaviour. People with different personalities perceive the seven HBM determinants differently, highlighting the need to personalize the determinants in persuasive intervention to individuals' personality types.

## 5 Discussion and Design Recommendations

The results presented in the previous section demonstrate that personality traits moderate the impact of the HBM determinants on physical activity. In summary, Extraversion emerged as the most influenced personality (it has a significant relationship with five determinants). On the other hand, Agreeableness and Neuroticism emerged as the least influenced personalities. To a high extent, these conclusions are in line with previous studies, which have also demonstrated that Extraversion is the most responsive to persuasive strategies, and Neuroticism is the least responsive [34]. This section discusses our findings regarding the seven determinants. Based on these findings, Sect. 5.1 provides design recommendations for personalizing persuasive interventions for promoting physical activities.

**Perceived Barriers.** The general model shows that Perceived Barrier is negatively associated with physical activity. However, the personality-based model indicates that only Conscientiousness is negatively associated with Perceived Barriers. People high in Conscientiousness could be demotivated by any persuasive intervention that emphasizes perceived barriers associated with physical activities. A possible explanation of this negative relation is that individuals high in Conscientiousness are efficient and planful. Also, they are responsible and tend to be reliable and thorough. Since they are responsible and reliable, they tend to do things perfectly, and therefore they avoid any source of obstruction or hindrance that may lead to imperfect work. Thus, exposing people high in Conscientiousness to barriers can influence them negatively; this is in line with the

HBM proposition. The results also show that other personalities do not show a significant response to Perceived Barriers.

**Cue to Action.** Triggers of a target behaviour are important for promoting healthy behaviours. The results from our models demonstrate that Cue to Action is an important motivator of physical activity for people high in *Extraversion* only. This result was surprising given the diverse cues employed in persuasive interventions, such as reminders, prompts, and alerts [32]. Also, previous studies found that Cue to Action is an effective way for promoting healthy behaviour for different groups (e.g., gamers types [33] and collectivist and individualist groups [1]). Nonetheless, this is actually an interesting finding because it reveals the impact of personality traits on the effectiveness of persuasive intervention employing the determinants to promote physical activity. Our results show how different personalities can be influenced differently. Besides, other studies also found that Cue to Action did not promote health behaviour in interventions [31, 32].

**Self-efficacy.** Our results revealed that Self-efficacy is significantly positively associated with Openness and Conscientiousness personalities. As mentioned above, individuals high in Conscientiousness are efficient, planful, and reliable. Therefore, they tend to be confident in their abilities and efficiency as they follow plans. Regarding Openness, individuals who are high in Openness are usually defined as open to experience because they often seek new and unfamiliar experiences. Thus, they have a high level of self-confidence to explore new and unfamiliar things. On the other hand, Self-efficacy demotivates people high in Neuroticism. This negative impact can be explained by the fact that people high in Neuroticism are characterized by several negative and unstable moods. These moods lead Neurotic individuals to interpret typical situations as threatening (i.e., they may respond negatively to ordinary situations) [46]. Thus, as Table 1 shows, two determinants are perceived as negative by people high in Neuroticism, but none of the determinants significantly impact them positively.

**Perceived Benefit.** Our results show that Perceived Benefit is a significant positive determinant for *Openness* and *Extraversion* personalities. This finding can be explained by two points. First, people high in Openness tend to be intellectually curious, and they are more inclusive in their thinking than other persons. Therefore, they are more inclusive in assessing the benefits of their actions. Thus, they are significantly influenced by the perceived benefit determinant. Second, regarding people high in Extraversion, they are known as active, energetic, outgoing, and impulsive by nature. They prefer to *do* activities rather than *think* about doing the activities. Thus, they are significantly influenced not only by Perceived Benefit but also by Cue to Action, Perceived Severity, Perceived Susceptibility, and Social Influence.

**Social Influence.** Social Influence emerged as a strong positive determinant for *Conscientiousness* and *Extraversion*. This result was expected, especially because individuals high in Extraversion are talkative, friendly, and social. Thus, they are highly influenced by social-related factors. On the other hand, Social Influence emerged as a significant determinant that impacts *Neuroticism* negatively. As mentioned above, this negative

association can be explained by the negative and unstable emotions that distinguish neuroticism personality.

**Perceived Severity.** We found that Perceived Severity is significantly associated with Extraversion only. This positive association implies that individuals people high in Extraversion care about the negative consequences of being physically inactive. As mentioned above, our results show that Extraversion is significantly associated with five determinants. Previous studies have also demonstrated that Extraversion emerged as the most responsive personality trait to persuasive strategies [34].

**Perceived Susceptibility.** Similar to Perceived Severity, the Perceived Susceptibility did not emerge as a strong determinant for any personality other than *Extraversion*. As mentioned before, because individuals high in Extraversion are active and enthusiastic, they are more likely to engage in new activities even without motivation. Their perception of the associated risk would increase the likelihood of their engagement in a new activity (physical behaviour in particular). On the other hand, Perceived Susceptibility is not associated negatively with any personality trait.

## 5.1 Design Recommendations

The previous section discusses how different determinants are associated with personality traits. This section builds on these results and provides recommendations for designing persuasive systems that are personalized based on the big five personality traits and informed by the HBM determinants. To do so, we relied on the established mapping between the HBM determinants and persuasive strategies introduced by Almutari and Orji [1] and depicted in Fig. 1. The mapping was done for the domain of promoting physical activity, and it was accomplished with the help of seven experts from several disciplines, including persuasive computing, human-computer interaction, and health.

**Table 3.** Sample mapping of determinants to persuasive strategies [1]

Determinant	Persuasive Strategies
Perceived Barriers	Suggestion, Extinction, Punishment, Negative reinforcement
Perceived Benefits	Reward, Gain-framed appeal
Cue to Action	Reminder, Suggestion
Self-efficacy	Incremental goal setting, Recognition, Feedback, Praise
Perceived Severity	Punishment, Negative reinforcement, Vicarious reinforcement, Simulation
Perceived Susceptibility	Self-monitoring, Loss-framed appeal, Simulation
Social Influence	Cooperation, Social Facilitation, Social learning, Comparison

Based on these mappings, and the mapping between Personality traits and HBM (depicted in Fig. 1), we provide the following recommendations for designing personalized persuasive interventions for promoting physical activity (Table 4).

**Table 4.** Mapping determinants to personality traits. “√” indicates strategies that can be used, “X” indicates strategies that should be avoided, and “-” indicates no strong correlation was found.

	BAR	BEN	CUA	EFF	SEV	SUS	SI
Openness	-	√	-	√	-	-	-
Conscientious	X	-	-	√	-	-	√
Extraversion	-	√	√	-	√	√	√
Agreeableness	-	-	-	-	-	-	-
Neuroticism	-	-	-	X	-	-	X

**Conscientiousness.** Individuals high in *Conscientiousness* are motivated mainly by two determinants, Self-efficacy and Social Influence. Thus, to motivate *conscientious* people to be physically active, **we recommend that designers deploy persuasive strategies that promote users’ confidence in their ability to perform healthy behaviours (i.e., self-efficacy-related strategies) or strategies that use the power of social influence.** A summary of these strategies is presented in Table 3. On the other hand, participants high in Conscientiousness are negatively influenced by Perceived Barriers. Therefore, designers **should avoid using strategies that allude to barriers associated with physical activity.** Strategies such as Negative reinforcement, punishment, and extinction should be avoided.

**Extraversion.** Our study shows that people high in Extraversion are the most influenced and easily motivated to engage in physical activity. Specifically, five determinants (Perceive Benefit, Cue to Action, Perceived Severity, Perceived Susceptibility, and Social Influence) emerged as strong motivators of people high in Extraversion. On the other hand, none of the determinants was found to have a significant negative impact on people high in Extraversion. These associations indicate that individuals high in Extraversion are motivated to be physically active by their perceptions of the good things related to being physically active (perceived benefit) and the risks and seriousness of the consequences of not being physically active (Severity). Therefore, **to design persuasive interventions targeted at promoting physical activity among people who are high in extraversion, designers could employ the benefit, cue to action, severity, susceptibility, and social influence related strategies.** Based on the established mapping (Table 3), using persuasive strategies, such as Rewards, Punishment, simulation, and self-monitoring, would increase the likelihood that extroverts will engage in physical activity. In addition, people high in Extraversion are motivated by factors that prompt physical activity (such as reminders and suggestions) and by social influence strategies (e.g., cooperation, social comparison, or social facilitation).

**Neuroticism.** Our findings demonstrate that none of the determinants significantly motivate people high in *Neuroticism* positively. On the other hand, two determinants (self-efficacy and social influence) negatively influence *Neuroticism* personality. Hence, any persuasive strategy that alludes to self-efficacy and social influence may negatively affect neurotic individuals. **Therefore, designers should avoid using persuasive**

**strategies, such as Goal Setting, Feedback, Cooperation, or Comparison, in persuasive intervention that promotes physical activities for people high in Neuroticism.** Again, designers should investigate other determinants that will motivate neurotics to be physically active.

**Openness.** People who are *Open* to experience (i.e., high in Openness) emerged as significantly positively influenced by two determinants, Perceived Benefit and Self-efficacy, and they are not influenced negatively by any determinant. **Therefore, to design persuasive interventions that promote physical activity among people who are high in Openness, designers could employ persuasive strategies associated with perceived benefit (e.g., Reward and Gain-Framed Appeal) and self-efficacy (e.g., Incremental Goal Setting, Feedback, Praise, and Recognition).**

**Agreeableness.** People high in Agreeableness are significantly associated with none of the seven determinants. That means none of the seven HBM determinants can significantly motivate people high in *Agreeableness* to be physically active. Hence, **we recommend that research explore more agreeableness-oriented determinants that can significantly motivate them to be physically active.** Another possible implication is that the HBM determinants do not generalize and cannot predict the likelihood of health behaviour for everyone.

## 6 Limitations

Despite our findings that can inform the design and development of persuasive applications for physical activity behaviour, there are limitations to applying our results. First, like most large-scale population-based research, our study relied on self-reported data that could be biased and may not accurately describe peoples' actual behaviour. That is, what is measured is peoples' belief rather than their actual behaviour. Second, although our work is based on a large-scale study, and the HBM model has been widely used in several health domains, we cannot confirm the validity of our models in domains other than physical activity behaviour. Therefore, applying our models' results in other domains should be done with caution. As part of our future work, we will apply our guidelines described above to design and evaluate a persuasive intervention tailored to the personality type.

## 7 Conclusions and Future Work

The literature has demonstrated the ability of the Health Belief Model (HBM) determinants to predict factors influencing health behaviours. It has also shown that personality influences many aspects of our lives. However, there is barely any research investigating whether personality moderates the impact of the HBM determinants on health behaviour, specifically in the area of physical activity. This work is a step toward filling this gap and developing a personalized persuasive mobile intervention. We conducted a large-scale study of 430 participants to explore the relationship between the big five personalities, the seven HBM determinants, and the likelihood of physical activity. Our model results

revealed differences between personality traits and the HBM determinants. These differences indicate that personality traits moderate the impact of the HBM determinants on physical activity behaviour. Hence, there is a need to tailor the HBM determinants to an individual's personality in persuasive intervention design. *Extraversion* emerged as the most influenced personality, with five determinants being strongly related to it. On the other hand, *Agreeableness* and *Neuroticism* are the least influenced, with no significant positive relationship with any of the determinants. Based on our findings and extensive study of the literature, we provided recommendations for designing persuasive interventions tailored to different personalities to motivate them to be physically active. As part of our future work, we will apply our guidelines described above to design and evaluate a persuasive intervention tailored to the personality type. Besides, we will also study the effect of users' demographics on the determinants of physical activities.

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