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Personality, motivational, and social cognition predictors of leisure-time physical activity☆,☆☆

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ABSTRACT

Objective: The purpose of the present study was to investigate associations between personality traits of extraversion and neuroticism, autonomous motivation, and the Theory of Planned Behavior (TPB) constructs and leisure-time physical activity. The study examined whether autonomous motivation and the TPB constructs mediate the association between personality traits and physical activity, and whether personality traits moderate the relationship of autonomous motivation and the TPB constructs with physical activity.

Methods: Middle-aged women (N = 441) completed self-report measures of personality traits, autonomous motivation, attitudes, subjective norms, perceived behavioral control (PBC) and intention. Moderate-to-vigorous leisure-time physical activity (MVPA) was measured using accelerometers approximately seven weeks later. Participants' past accelerometer-based MVPA was available from four years earlier.

Results: Only autonomous motivation and past MVPA directly predicted MVPA. Neuroticism and past MVPA were indirectly related with MVPA through autonomous motivation. No support for a moderator role of personality traits was found.

Conclusions: Current data suggest that autonomous motivation and past experience are prominent determinants of accelerometer-based leisure-time MVPA, but not beliefs and intentions.

1. Introduction

Regular participation in moderate-to-vigorous physical activity (MVPA) has well-known physical and psychological benefits (Warburton, Nicol, & Bredin, 2006). However, levels of physical inactivity are high in many populations globally, and this has been recognised as a major public health issue (Guthold, Stevens, Riley, & Bull, 2018). Insufficient physical activity is a problem, especially among women and older adults (Sallis et al., 2016), and in women, a decrease in physical activity seems to occur a few years before menopause, after which physical activity remains low (Duval et al., 2013; Lovejoy, Champagne, de Jonge, Xie, & Smith, 2008). To be optimally efficacious, initiatives aimed at promoting physical activity need to be based on a fundamental understanding of physical activity behaviours and the factors that contribute to them (Hagger & Weed, 2019). One approach is to focus on dispositional personality traits and more modifiable motivational and social cognition factors (Coulter, Mallett, Singer, & Gucciardi, 2016; McAdams, 1995).

The relatively stable dispositional characteristics of personality are captured by personality measures (McAdams, 1995). The most

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prominent conceptualization of personality traits is captured by the 'Big Five' or five-factor model (FFM) (McCrae & Costa, 2003), which arose from previous taxonomies (e.g. Cattell, 1943; Eysenck & Eysenck, 1971). Two of the traits from the FFM, extraversion and neuroticism, represent the core dimensions of personality and have been shown to have important influences on various behavioral tendencies (Eysenck & Eysenck, 1975). Extraversion represents a generalised tendency to be attracted to and seek out social interactions and be active, while neuroticism describes the extent to which individuals express emotional stability (Eysenck & Eysenck, 1975; McCrae & Costa, 2003). Importantly, these traits may also relate to individuals' tendencies to participate in regular physical activity: studies have shown that individuals expressing high levels of extraversion are more likely to participate in physical activity, while those exhibiting high levels of neuroticism tend to be less physically active (Sutin et al., 2016; Wilson & Dishman, 2015). This is consistent with the idea that people scoring high in extraversion have a tendency to seek out intense stimulation, whereas people scoring high in neuroticism may perceive this kind of stimulation negatively (Eysenck & Eysenck, 1971; Wilson & Dishman, 2015).

Notwithstanding, the associations between personality traits and physical activity are generally modest in size (Sutin et al., 2016; Wilson & Dishman, 2015), partly because personality traits reflect generalised tendencies and are not focused on particular behaviors, such as physical activity. This means that there are more psychological factors more relevant to specific contexts that are more likely to exhibit stronger relations with the target behavior as they reflect specific information and will have closer temporal and context correspondence (Ajzen, 1991). These more factors reflect people's beliefs and motives, which are more dependent on not only the context in which the behavior is performed, but also a person's previous experience (past behaviors) and generalised traits. Personality traits are likely to influence these beliefs and motives (Rhodes & Pfaeffli, 2012) and these more behavior-specific factors may mediate the link between personality traits and physical activity (Coulter et al., 2016; Ferguson, 2013; Wilson, 2019; Wilson & Rhodes, 2021). Theories that may help identify these behavior and context-relevant motives and beliefs include Self-Determination Theory (SDT; Deci & Ryan, 1985; Ryan & Deci, 2000) and the Theory of Planned Behavior (TPB; Ajzen, 1985; 1991).

SDT is the leading theory in human motivation. The forms of motivation in SDT are conceptualized on a continuum ranging from autonomous to controlled motivation (Deci & Ryan, 1985; Ryan & Deci, 2000). The prototypical form of autonomous motivation is intrinsic motivation, which reflects reasons to perform a behavior due to the inherent enjoyment or interest an individual derives from the behavior. In contrast, the prototypical form of controlled motivation is external regulation, which reflects the performance of a behavior for external reasons, such as to gain a reward or avoid punishment (Ryan & Deci, 2000). Empirical evidence consistently supports the positive association between more autonomous motivation styles and participation in physical activity (Teixeira, Carraça, Markland, Silva, & Ryan, 2012). Notwithstanding, the different reasons to be physically active could reflect individual differences in personality traits (Prentice, Jayawickreme, & Fleeson, 2019). Research has indicated that neuroticism is associated with controlled forms of motivation, such as participating in exercise for appearance and weight management, while extraversion is positively associated with more autonomous regulation styles (Ingledew & Markland, 2008; Ramsey & Hall, 2016). This implies a negative indirect effect of neuroticism and positive indirect effect of extraversion on physical activity, mediated by motivational styles from SDT.

Autonomous motivation may lead to behavior through either non-conscious or, more likely, deliberative processes (Hagger & Chatzisarantis, 2009). Individuals are likely to align their beliefs toward behaviors according to their motivational regulations and these beliefs are important predictors of both intention and actual behavior. Prominent among different theories that focus on deliberative processes is the TPB (Ajzen, 1985, 1991), which has been applied extensively in physical activity contexts and its constructs have been shown to explain substantive variance in intentions toward, and actual participation in, physical activity (Armitage & Conner, 2001; Hagger & Chatzisarantis, 2009). A central premise of the TPB is that intention, a motivational construct reflecting an individual's estimate of how much they plan or are willing to invest effort in pursuing a *target* behavior, is the most proximal determinant of behavior (Ajzen, 1985, 1991). Intention is based on an individual's beliefs that the target behavior will lead to desired outcomes (attitudes), that significant others would like the individual to participate in the behavior (subjective norms), and that they have the personal resources to perform the behavior (perceived behavioral control; PBC) (Ajzen, 1985, 1991). In the context of physical activity, attitudes and PBC tend to have the largest effects on intentions and, indirectly, behavior (Hagger, Chatzisarantis, & Biddle, 2002). PBC is also proposed as a direct predictor of behavior because it reflects actual constraints on the behavior (Ajzen, 1985, 1991).

Research has also highlighted the imperative of including past behavior in tests of the TPB (Ajzen, 1991; Hagger & Chatzisarantis, 2014; Hagger, Polet, & Lintunen, 2018, 2002). Direct effects of past behavior on the subsequent behavior may represent habitual and non-conscious processes that lead to behavior (Hagger, 2019). In order for the TPB to provide sufficient prediction of behavior, its determinants should explain unique variance in behavior beyond past behavior and should also account for its consistency over time (Ajzen, 1991), but this may not always be the case (Chatzisarantis, Hagger, Biddle, & Karageorghis, 2002; Rodrigues, Teixeira, Neiva, Cid, & Monteiro, 2020). Direct effects of past behavior on subsequent behavior may model unmeasured constructs not included in the model, particularly those that bypass intentions such as habits and implicit processes (Ajzen, 1991).

If a behavior is viewed as autonomous, individuals will strategically align their beliefs (attitudes, subjective norm, and PBC) with those motives that will, in turn, lead them to form intentions to perform the behavior in future (Hagger & Chatzisarantis, 2014). Consistent with this theorizing, studies integrating the TPB and SDT, including those on physical activity participation, have shown that autonomous motivation has positive relationship with TPB constructs, particularly attitudes and PBC, and these constructs mediate the association of autonomous motivation with intention and behavior (Chan, Zhang, Lee, & Hagger, 2020; Hagger & Chatzisarantis, 2009; Jacobs, Hagger, Streukens, De Bourdeaudhuij, & Claes, 2011). However, research has shown residual effects of autonomous motivation on physical activity behavior, suggesting that intentions may not be fully involved in the process by which autonomous motivation relates to behavior, or its measurement may be inadequate in capturing the process (Arnautovska, Fleig, O'Callaghan, & Hamilton, 2019).

This implies that the effects of personality traits on physical activity may be mediated by autonomous motivation alone, or by both the TPB constructs and autonomous motivation. In addition, personality traits may have direct associations with the TPB constructs: there is some evidence that extraversion is positively and neuroticism negatively associated with intention, attitudes and PBC (Courneya, Bobick, & Schinke, 1999; Rhodes, Courneya, & Hayduk, 2002). Furthermore, consistent with the predictions of the TPB, belief-based constructs partly mediate the association between personality traits and physical activity participation (Courneya et al., 1999), but full mediation is not supported (Rhodes& Pfaeffli, 2012). In addition to the TPB constructs, personality traits relate to physical activity through two separate processes (Rhodes & Pfaeffli, 2012). In line with dual-process theories of behavior, personality traits may be linked to physical activity through both reasoned, conscious processes captured by the TPB and more impulsive, non-conscious affective processes captured by direct effects on behavior (Hagger, 2016; Hagger et al., 2019; Strack & Deutsch, 2004).

This non-conscious process may explain why intention, even as one of the strongest predictors of physical activity behavior (Armitage & Conner, 2001; Hagger et al., 2002), is not always implemented and lead to actual behavior (Rhodes & Bruijn, 2013). It has been suggested that intention may not capture all motivational domains (Rhodes & Bruijn, 2013), and personality traits may moderate this intention–behavior gap (Rhodes, Courneya, & Hayduk, 2002; Rhodes & Dickau, 2013). People scoring high in extraversion, for example, may seek more opportunities to be physically active and therefore display a stronger relationship between intention and actual physical activity behavior compared to people who score low in extraversion (Rhodes, Courneya, & Hayduk, 2002; Rhodes & Dickau, 2013). In contrast, the negative emotions experienced by those high in neuroticism may lead to a diminished intention–behavior link although most research has not , supported this moderating effect (Rhodes, Courneya, & Hayduk, 2002; Rhodes & Dickau, 2013).

In the present study, we aimed to apply an integrated model to examine the relationships between the personality traits of extraversion and neuroticism, autonomous motivation, TPB variables and accelerometer-based physical activity among a population-based sample of middle-aged women. Our focus was on leisure-time physical activity, including active commuting, as individuals can influence this type of physical activity.[1] The study presents several unique predictions. First, although both autonomous motivation and the TPB constructs have been studied previously as mediators of relations between personality traits and physical activity, they have not been studied in the same model. By integrating multiple theories in this study, we aimed to provide a comprehensive explanation of variance ub physical activity behavior. Second, we adopted an accelerometer-based measure of physical activity, which has been less utilized in studies examining the associations between psychological constructs and physical activity. This is important given that preliminary evidence suggests that the associations between constructs from social cognition and motivational theories such as the TPB (Scott, Eves, French, & Hoppé, 2007) and personality constructs such as extraversion (Kekäläinen, Laakkonen, et al., 2020; Wilson, Das, Evans, & Dishman, 2015) tend to be smaller with device-based physical activity than self-reported physical activity.

Consistent with the research reviewed above, we proposed two models. The first model (Figure 1) hypothesized that personality traits have both direct (H1) and indirect associations with prospectively measured MVPA through autonomous motivation and the TPB constructs (H2–H5). We contended that these associations would remain when past MVPA was included in the model (H6 and H7). The second model hypothesized that the associations between autonomous motivation, intention and PBC with MVPA (H2) would be moderated by personality traits (H8).

H1: Extraversion and neuroticism are directly associated with MVPA.

H2: Intention, PBC and autonomous motivation are directly associated with MVPA.

H3: Attitudes, subjective norms and PBC are indirectly associated with MVPA through intention.

H4: Autonomous motivation is indirectly associated with MVPA through attitudes, subjective norms, PBC and intention.

H5: Extraversion and neuroticism are indirectly associated with MVPA through autonomous motivation, attitudes, subjective norms, PBC and intention.

H6: Past MVPA is directly associated with MVPA and indirectly associated with autonomous motivation, attitudes, subjective norms, PBC and intention.

H7: The proposed model effects in H1–H5 remain after controlling for the effects of past physical activity behaviours.

H8: Extraversion and neuroticism moderate the hypothesized (H2) associations between autonomous motivation, intention, PBC, and MVPA.

[1] Throughout the text, we use the term 'physical activity' to refer to leisure-time physical activity, which includes active commuting but excludes occupational physical activity.

2. Methods

2.1. Participants

This is a secondary analysis of a data from the Estrogen, microRNAs and the risk of metabolic dysfunction (EsmiRs) study (Hyvärinen et al., 2021; Kekäläinen et al., 2021). The focus of EsmiRs study is on biological mechanisms behind menopause and menopause-related health changes. The EsmiRs study is a four-year follow-up study for the Estrogenic Regulation of Muscle Apoptosis (ERMA) study, a population-based cohort study of 47–55 year-old women living in the city of Jyväskylä, Finland and neighboring municipalities (Kovanen et al., 2018). Flow of participants whose data were used in the present research through the study is shown in Figure 2. Participants were recruited to the ERMA study by random selection from the Population Information System administered by the Digital and Population Data Services Agency. Exclusion criteria were self-reported body mass index (BMI) > 35, being currently pregnant or lactating, conditions or medications affecting ovarian function, and chronic diseases or medications seriously affecting muscle function or reducing physiological functional capacity. Invitation letter was sent to 6878 eligible women with 47% ($N = 3229$) agreeing to participate. After exclusions and drop-out, a final sample of 1393 women participated in an initial laboratory visit, during which they were asked for their consent to be invited to further participate in the study and to be contacted in future for new studies. This permission was given by 811 women who were invited by postal inquiry to participate in EsmiRs study about four years later.

To conclude, inclusion criteria for the EsmiRs study were that a participant was a former ERMA study participant and that she had provided consent to be contacted for future research invitations. EsmiRs study contained two phases. Phase one included postal invitation accompanied by a paper-and-pencil questionnaire and consent forms. Of the contacted 811 women, 64% responded and 494 returned questionnaires including self-reported physical activity questions and all psychological questionnaires (n = 28 declined to participate). Phase two contained laboratory visits. Women who self-reported to have more than seven years since menopause (n = 46) or who had severe cardiovascular dysfunction or insulin treated diabetes (n = 4) were excluded from the laboratory visit. Furthermore, 25 did not consent for laboratory visit, and 16 discontinued before laboratory visit. Accelerometers were offered to participants during the laboratory visit to be used for seven consecutive days.

The data collection for the EsmiRs study started in November 2018, and laboratory measures including delivery of accelerometer were suspended on March 16, 2020 because of the outbreak of COVID-19 pandemic led university to temporally close its facilities. Those participants ($n = 101$) who had not participated in the study before this time were sent an invitation to participate but they only completed the self-reported questionnaires. Those participants ($n = 441$) who had completed the questionnaire prior to March 16 were included in the present study. Acceptable accelerometer-based information comprising at least 3 days activity data and at least 10 h wear time was available for 288 participants.[2]

The Ethics Committee of the Central Finland Hospital district approved the ERMA (8U/2014) and the EsmiRs (9U/2018) studies. Participants signed an informed consent form and were allowed to withdraw their consent at any time during the study or for any individual part of the study.

2.2. Measures

Full details of all measures are available in Supplementary Materials

[2] Participants completed study measures prior to the introduction of national lockdown measures aimed at curbing the COVID-19 pandemic.

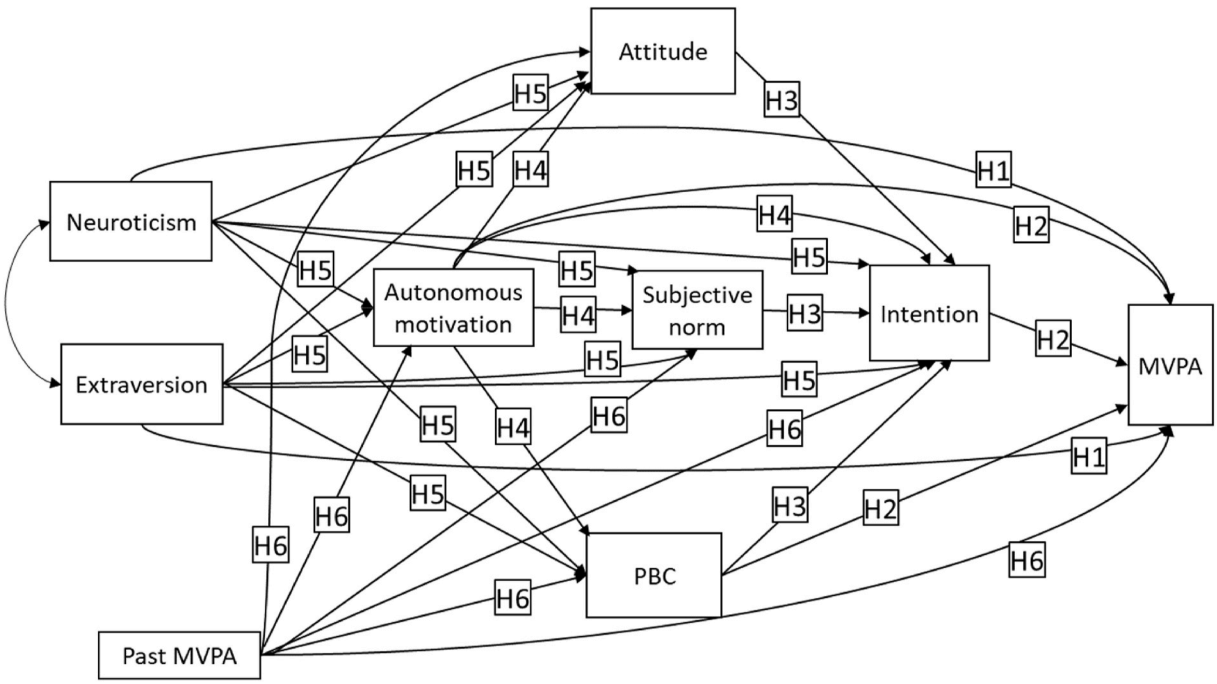

Fig. 1. Hypothesised path model.

(Table S1).

Personality traits: Extraversion and neuroticism were assessed using the modified short form of the Eysenck Personality Inventory (Floderus, 1974). The inventory includes 19 statements: nine for extraversion (e.g. 'Are you lively and talkative?') and 10 for neuroticism (e.g. 'Are you extremely sensitive in some situations?'), with responses provided on binary scales (0 = no and 1 = yes). The extraversion and neuroticism scales are formed by computing the sum of the scale items. Because a missing value may cause the sum of the scores to be too low, in this study they were imputed based on the scores of the adjacent items in the same scale (Chapman, Weiss, Barrett, & Duberstein, 2013). Nine participants had a single item missing among the extraversion items, and 12 participants had one or two missing items among the neuroticism items.

Autonomous motivation: Autonomous motivation was assessed using an adapted version of Ryan and Connell's (1989) perceived locus of causality questionnaire. Participants responded to eight statements describing reasons why they exercise in their leisure-time preceded by the common stem: "I exercise …". Two items evaluated intrinsic motivation (e.g., "… because I enjoy exercise"), identified regulation (e.g., "… because I value the benefits of exercise"), introjected regulation (e.g., "… because I will feel guilty if I don't exercise"), and external regulation (e.g., "… because other people will be dissatisfied with me if I don't exercise"). Previous studies adopting this adapted measure have reported adequate construct, predictive, and nomological validity statistics, and acceptable internal consistency estimates, in multiple populations and behaviors, including physical activity (e.g., Hagger, Chatzisarantis, Culverhouse, & Biddle, 2003; Hagger et al., 2006; Hamilton, Kirkpatrick, Rebar, & Hagger, 2017). A relative measure of autonomous motivation was calculated by assigning the weights of −2, −1, +1, and +2 to the mean values of the external, introjected, and identified regulation, and intrinsic motivation items, respectively (Grolnick & Ryan, 1987).

The TPB Constructs: Measures of the TPB variables were developed according to the published guidelines (Ajzen, 1991; Fishbein & Ajzen, 2010). Intention ("I intend to do active sports and/or vigorous physical activities during my leisure-time in the next five weeks"), PBC ("I am confident I can do active sports and/or vigorous physical activities during my leisure-time in the next 5 weeks"), and subjective norm ("Most people who are important to me think I should do active sports and/or vigorous physical activities during my leisure-time in the next five weeks") were single-item measures with responses provided on seven-point scales (1 = *strongly disagree* and 7 = *strongly agree*). Attitude was measured in response to the following common item: "Participating in active sports and/or vigorous physical activities during my leisure-time in the next five weeks will be …", with responses provided on two items using seven-point scales (1 = *unenjoyable* and 7 = *enjoyable* and 1 = *of no use*, 7 = *useful).* The attitude measure comprised the mean value of these two items (Pearson correlation between items $r = 0.39$, $p < .001$).

MVPA: Accelerometer-based leisure-time physical activity was assessed prospectively using triaxial GT3X+ and wGT3X + ActiGraph accelerometers (Pensacola, FL). During their laboratory visit, the participants were instructed to wear the accelerometer on their right hip for seven consecutive days during waking hours except when bathing or performing other water-based activities. The accelerometers were retrieved by mail after the seven-day period. The accelerometer measurement period started on average seven weeks after the completion of the questionnaire assessing the participants' psychological characteristics ($M = 50.7$ days, $SD = 30.6$, range = 12–228).[3] The data were collected at a frequency of 60 Hz, filtered and converted into 60-s epoch counts. Subsequently, the mean times spent at different physical activity intensities (sedentary, light, moderate and vigorous) were assessed using the triaxial vector magnitude cut-off points of 450, 2690 and 6166 counts per minute, respectively (Laakkonen et al., 2017; Sasaki, John, & Freedson, 2011). The information about leisure-time MVPA was used in the present study.

The accelerometer measurements were accompanied by diaries in which the participants recorded their wake-up times, working hours and periods when the monitor was removed for longer than 30 min

[3] The questionnaire was mailed to the participants together with a study invitation, and a laboratory visit, which included the delivery of a accelerometer, was scheduled after consent to participate had been obtained. The time gap between the questionnaire completion and the accelerometer delivery was dependent on each participant's availability for a laboratory visit.

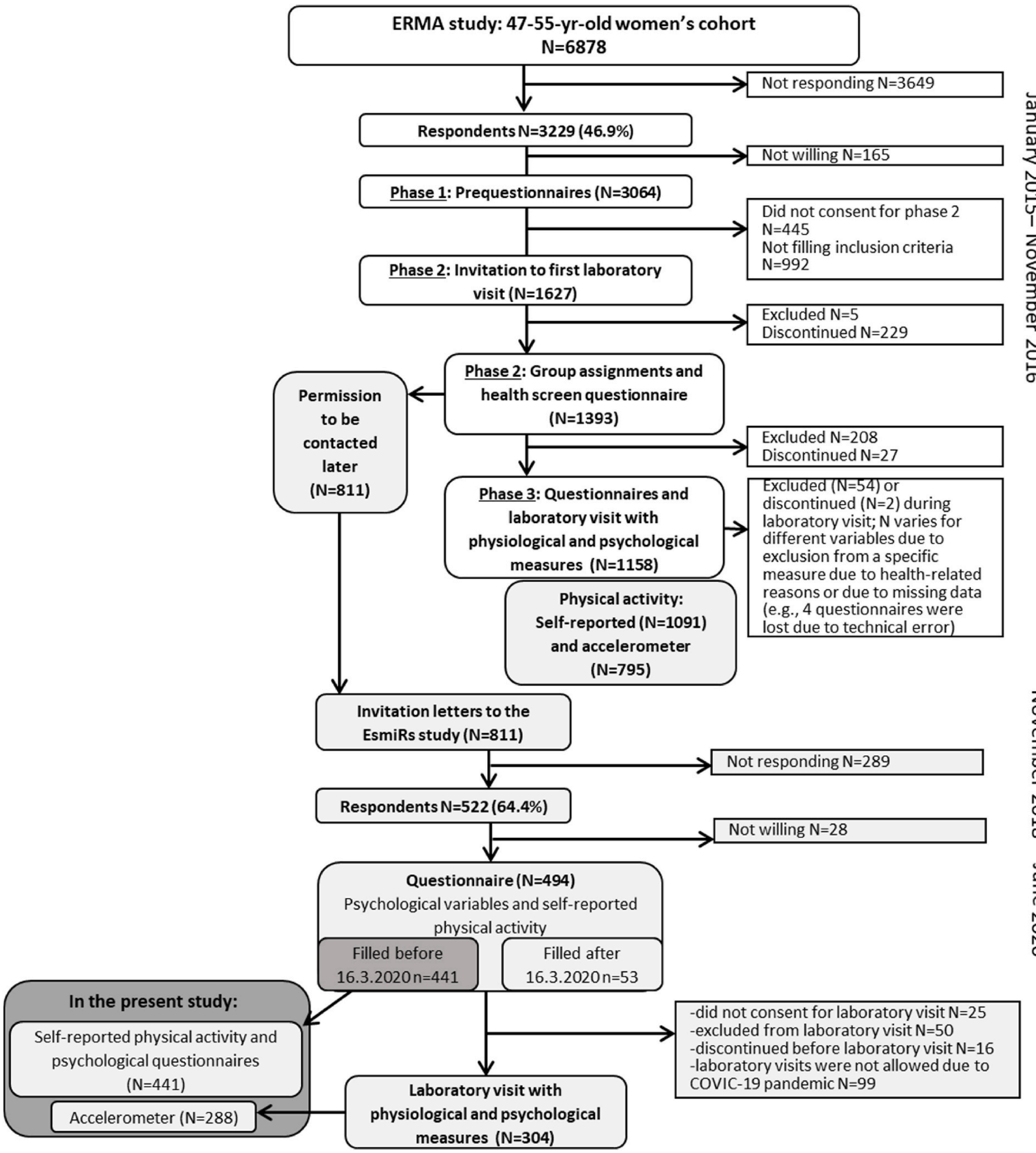

Fig. 2. Chart describing the flow of the participants through the study.

(Hyvärinen et al., 2020). The diaries were used to separate working and leisure time. Periods of at least 60 min of continuous zero counts were defined as non-wear time (Migueles et al., 2017). Wear time of at least 10 h per day on at least three days was required. To account for inter-individual differences in wearing time, the mean daily minutes of leisure-time physical activity were normalised to 10 h wearing time (Brakenridge et al., 2016; Hyvärinen et al., 2020). Identical information was obtained from the ERMA baseline study to indicate the participants' physical activity behaviours approximately four years previously (M = 3.8 years, SD = 0.14, range = 3.6–4.7). Of the 441 women included in this study, 315 (71.4%) women had valid accelerometer data from the ERMA baseline study.

2.3. *Statistical analysis*

Independent samples *t*-tests and χ^2-tests were used to compare differences in education, marital status, age, body mass index (kg/m^2), physical activity level, and personality traits for participants in the present study and participants from the original ERMA sample. In addition, data were expected to be missing completely at random (Little's MCAR test for study variables $p > .05$) and missing values were handled using maximum likelihood estimation that utilizes all available data.

Hypothesised relations among study variables were tested using a path analysis using the Mplus software with a maximum likelihood (ML) estimation method. The goodness-of-fit χ^2-test, the comparative fit index (CFI), Tucker-Lewis index (TLI), standard root mean residual (SRMR), and the root mean square error of approximation (RMSEA) with its 90%

Confidence Interval (CI 90%) were used as the criteria of overall goodness-of-fit of the estimated models. An acceptable model is indicated by a non-significant χ^2-test, CFI and TLI values $\geq$ 0.95, and SRMR and RMSEA values $\leq$ 0.08 (Hu & Bentler, 1999).

The data were expected to be completely missing at random (Little's MCAR test for study variables, p > .05), and the missing values were handled using maximum likelihood estimation, which utilised all the available data.

Two sets of path models were estimated. The first path models (Figure 1) investigated whether personality traits have direct or indirect associations with MVPA through autonomous motivation and the TPB constructs. Path models with and without past MVPA were analyzed. The second set of path models investigated whether personality traits moderate associations between autonomous motivation, the TPB constructs, and MVPA. The moderation analyses were conducted using moderation models (Stride, Gardner, Catley, & Thomas, 2015) consistent with Hayes' work on bootstrapped moderated regression and path analyses (Hayes, 2017). In line with the focus of the present study, a total of six moderator analyses were conducted to test the moderating effects of extraversion and neuroticism on the associations of intention, PBC and autonomous motivation with MVPA. The time gap between the completion of the questionnaire and the accelerometer measure of MVPA was included as a covariate in all the models.

3. Results

3.1. Descriptive statistics

The mean age of the women in the current sample ($n = 441$) was 54.7 ($SD = 2.0$) years, and the mean self-reported BMI was 25.8 ($SD = 4.1$). About three quarters (73.5%) of the participants were married or cohabiting, and the balance (26.5%) were single, divorced, widowed or in a relationship but living separately. Only 1.1% of the participants had lower secondary education, while 54.9% had upper secondary education, and 44.0% had tertiary or higher education. The descriptive statistics of the study variables and the zero-order correlations among them are presented in Table 1. A comparison of the analytic sample to the Finnish population and the ERMA baseline study are presented in the Supplementary Material (Tables S2 and S3). The analytic sample did not differ from the ERMA baseline sample (Table S3). The analytic sample was more educated than the Finnish population sample (χ^2 test, $p < .05$) and likely to be more physically active (statistical testing not possible).

3.2. Path models

The first path model, which excluded past physical activity, was analysed in line with the hypothesized model presented in Figure 1. In addition to the hypothesized model, the time gap between the completion of the questionnaire and the accelerometer measure of MVPA was included as a covariate by including a path from the time gap to the MVPA. The model fit was not adequate: $\chi^2 = 207.17$, $df = 12$, $p < .001$; CFI = 0.809; TLI = 0.476; SRMR = 0.085, RMSEA = 0.192, 90% CI 0.170–0.215. High-modification indices suggested that correlations be allowed between the residuals of attitude, social norms and PBC (modification indices: 144.43 for PBC with attitude, 15.187 for subjective norms with attitude, and 19.039 for subjective norms with PBC). The second model, in which residual terms between attitude, social norms and PBC were allowed to be correlated, showed an adequate fit: $\chi^2 = 9.68$, $df = 9$, $p = .377$; CFI = 0.999; TLI = 0.998; SRMR = 0.021, RMSEA = 0.013, 90% CI 0.000–0.056. The similar path model, which included past MVPA, also showed an adequate fit: $\chi^2 = 9.94$, $df = 9$, $p = .355$; CFI = 0.999; TLI = 0.996; SRMR = 0.018, RMSEA = 0.015, 90% CI 0.000–0.057. The standardized parameter estimates for the models are presented in Figures 3 and 4, and summaries of the indirect and direct effects in each model are presented in Table 2. All the specific indirect effects (Table S5) and standardized residual variances for the variables (Table S6) are presented in the Supplementary Material.

In the model that excluded past physical activity (Figure 3), autonomous motivation was positively associated with MVPA (β = 0.21, p = .001), which was consistent with our hypothesis (H2). However, contrary to our hypotheses (H1 and H2), personality traits, intention, and PBC were not directly associated with MVPA. Neuroticism was negatively associated with autonomous motivation (β = −0.25, $p < .001$; H5) and had a negative indirect association with MVPA through autonomous motivation (specific indirect effect, β = −0.05, $p = .007$), as predicted. Counter to the other hypotheses, neuroticism was not associated with any TPB construct, and extraversion was not associated with autonomous motivation or the TPB constructs. Consequently, there was no indirect association between extraversion and physical activity mediated by any of the other variables in the model. The model explained 12% of the variance in MVPA. Excluding the participants with more than a two-month gap between measures did not change the results (Supplementary Material, Table S4).

In the model that included past physical activity (Figure 4), past MVPA was the most pervasive predictor of MVPA (β = .50, $p < .001$), which was consistent with our hypothesis (H6). Furthermore, past MVPA was positively associated with autonomous motivation (β = 0.24, $p < .001$), attitude (β = 0.14, $p = .005$), PBC (β = 0.16, $p = .003$) and intention (β = 0.07, $p = .023$) and had a statistically significant indirect association with MVPA (total indirect association, β = 0.05, $p = .011$), mainly through autonomous motivation (specific indirect association, β = 0.03, $p = .047$). All the associations found in the previous model that excluded past physical activity (i.e. the direct association between autonomous motivation and MVPA as well as the indirect association between neuroticism and MVPA) remained statistically significant, as hypothesised (H7). The model explained 33% of the variance in MVPA. Excluding the participants ($n = 67$) with more than a two-month gap between measures attenuated the direct association between autonomous motivation and MVPA (β = .13, $p = .057$) as well as the indirect association of past MVPA with MVPA (total indirect β = 0.04, $p = .064$) (Supplementary Material, Table S4).

The model shown in Figure 3, which excludes personality traits, was used as the basis for the moderator analyses of personality traits. The results of the moderator analyses are shown in Table 3. Neither

Table 1
Descriptive statistics and bivariate correlations among the study variables.

	n	M	SD	1	2	3	4	5	6	7	8
1. Extraversion	440	5.34	2.65								
2. Neuroticism	440	2.66	2.12	-.39*							
3. Autonomous motivation	441	21.44	10.26	.16*	-.28*						
4. Attitude	441	5.90	1.19	.12*	-.18*	.54*					
5. Subjective norm	441	3.76	2.00	.02	-.02	-.08	.11*				
6. PBC	441	5.82	1.40	.10*	-.21*	.47*	.68*	.15*			
7. Intention	440	5.32	1.66	.11*	-.17*	.53*	.71*	.15*	.78*		
8. MVPA	288	37.49	20.83	.01	-.06	.29*	.22*	-.05	.26*	.26*	
9. Past MVPA	315	39.87	20.21	-.05	-.01	.22*	.25*	-.01	.22*	.30*	.56*

Note. PBC = Perceived behavioral control, MVPA = Accelerometer-based moderate-to-vigorous leisure-time physical activity. *$p < .05$.

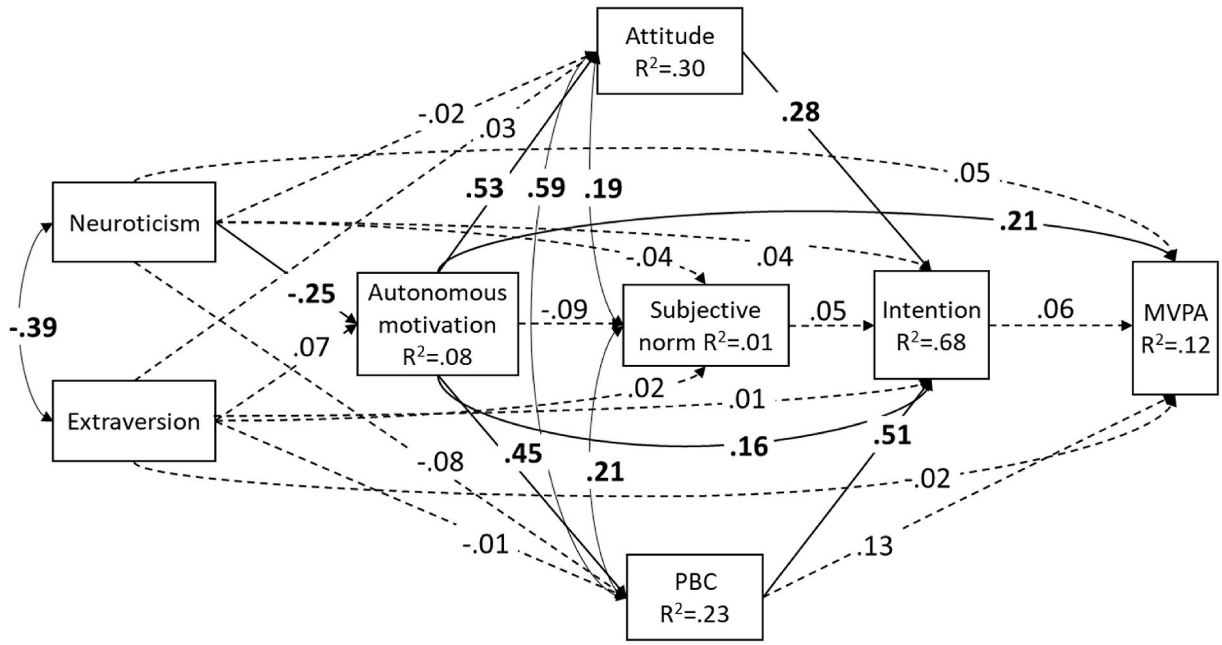

Fig. 3. Proposed model showing relations among study variables excluding past physical activity.
Note. Coefficients shown are standardized parameter estimates. Statistically significant paths ($p < .05$) are shown in solid lines and bolded estimates. Correlations between attitude, subjective norm and PBC are correlations between residual variances. Residual variances are not shown in the figure. Model adjusted for the time gap between completion of the questionnaire and the accelerometer-measure of MVPA.

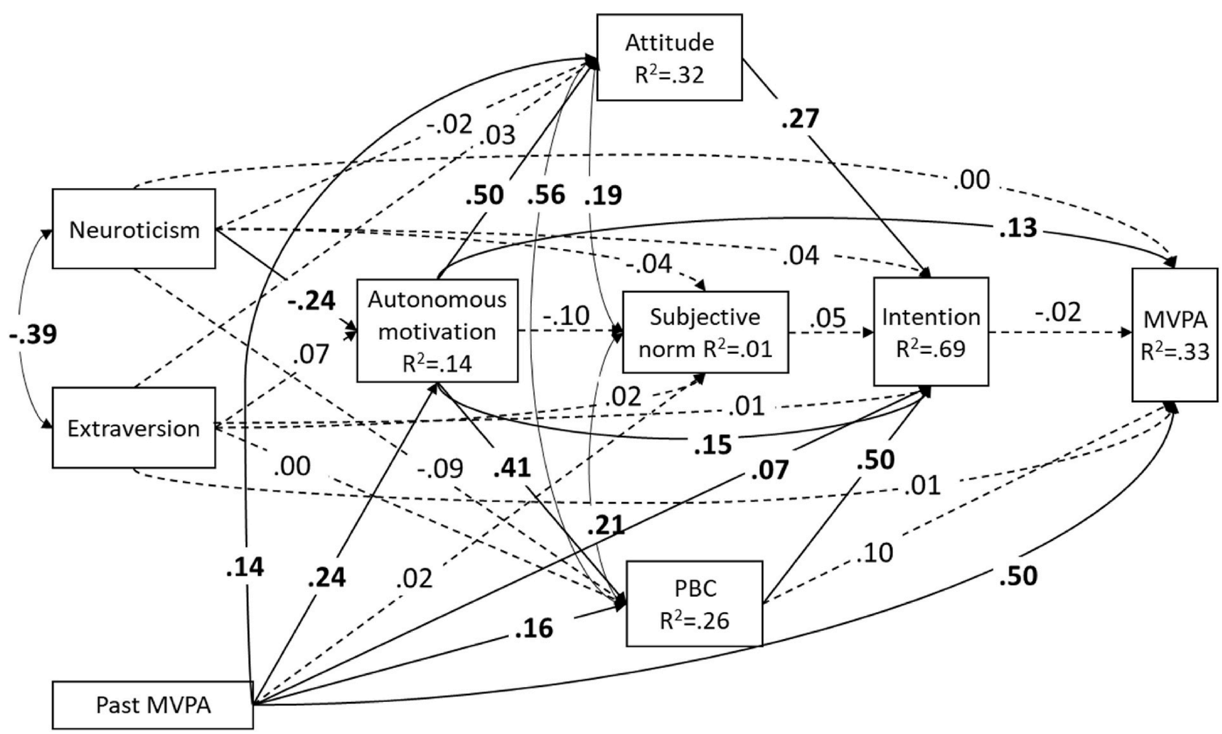

Fig. 4. Proposed model showing relations among study variables including past physical activity.
Note. Coefficients shown are standardized parameter estimates. Statistically significant paths ($p < .05$) are shown as solid lines and bolded estimates. Correlations between attitude, subjective norm and PBC are correlations between residual variances. Residual variances are not shown in the figure. Model adjusted for the time gap between completion of the questionnaire and the accelerometer-measure of MVPA.

neuroticism nor extraversion moderated associations between autonomous motivation, intention, and PBC with MVPA.

4. Discussion

In the present study, we applied an integrated model to examine relationships between personality traits, social cognition and motivational constructs, and leisure-time physical activity in a population-

Table 2
Standardized parameter estimates for total indirect and direct effects for the structural equation model.

Effects	Model excluding past physical activity			Model including past physical activity		
	β	SE	*p*	β	SE	*p*
Direct effects						
Neuroticism →MVPA	.046	.065	.478	.004	.059	.950
Extraversion →MVPA	-.019	.064	.769	.007	.057	.905
Autonomous motivation →MVPA	.213	.067	.001	.129	.062	.037
PBC→MVPA	.129	.091	.155	.095	.082	.247
Intention → MVPA	.060	.094	.526	-.019	.084	.823
PB MVPA→MVPA	–	–	–	.500	.049	<.001
Total indirect effects[a]						
Neuroticism →MVPA	-.087	.023	<.001	-.047	.017	.007
Extraversion →MVPA	.020	.017	.264	.011	.010	.245
Autonomous motivation →MVPA	.091	.038	.017	.030	.031	.339
Attitude →MVPA	.017	.027	.528	-.005	.023	.823
Subjective norm →MVPA	.003	.005	.555	-.001	.004	.825
PBC→MVPA	.031	.049	.526	-.009	.042	.823
PB MVPA→MVPA	–	–	–	.049	.019	.011
Total effects[b]						
Neuroticism →MVPA	-.041	.065	.524	-.043	.057	.448
Extraversion →MVPA	.001	.066	.990	.018	.058	.754
Autonomous motivation →MVPA	.304	.055	<.001	.159	.055	.004
PBC→MVPA	.160	.068	.018	.085	.062	.171
PB MVPA→MVPA	–	–	–	.549	.044	<.001

Note. [a]Sum of indirect effects on physical activity through all possible model constructs; [b]Total effect comprising sums of all indirect effects through model constructs plus the direct effect. Total effects shown only for variables including both direct and indirect effect, otherwise direct or total indirect effect is identical to total effect. β = Standardized parameter estimate; SE = Standard error of the standardized parameter estimate, MVPA = accelerometer-based moderate-to-vigorous leisure-time physical activity, PBC = Perceived behavioral control, PB=Past behavior.

based sample of middle-aged women. Two alternative roles for personality traits were investigated: personality traits as distal predictors of MVPA through autonomous motivation and the TPB constructs, and personality traits as moderators of the associations between autonomous motivation and the TPB constructs and MVPA. Consistent with our hypotheses, neuroticism had a negative indirect association with MVPA through autonomous motivation. However, contrary to our hypotheses, the TPB constructs were not associated with either MVPA or personality traits. Moreover, we found no support for our moderation hypotheses.

The main finding of the current study is that accelerometer-based physical activity behavior could be predicted directly by autonomous motivation and past physical activity, and indirectly by neuroticism and past physical activity through autonomous motivation. These results are in line with those of previous studies indicating that autonomous motivation is related to more frequent physical activity participation (Teixeira et al., 2012), past behavior has pervasive effects on subsequent physical activity behavior (Chatzisarantis et al., 2002; Hagger & Chatzisarantis, 2009; Hagger et al., 2018), and people who score high in neuroticism are less likely to report autonomous motivation towards physical activity (Ingledew & Markland, 2008; Ramsey & Hall, 2016).

The negative association between neuroticism and autonomous motivation found in this study is also consistent with the theoretical assumption that people who score high in neuroticism are less likely to enjoy the high stimulation derived from physical activity (Eysenck & Eysenck, 1971; Wilson & Dishman, 2015). People scoring high in neuroticism are more likely to report more barriers to exercise (Courneya & Hellsten, 1998), and are also more likely to exercise for weight and appearance purposes (Ingledew & Markland, 2008; Teixeira et al, 2020). These findings and our results suggest that people who score high in neuroticism may derive particular benefit from behavior change techniques that focus on improving autonomous motivation. These include techniques that target basic needs (i.e. relatedness, competence and autonomy; Hagger & Protogerou, 2020). There is also evidence that high barrier self-efficacy, which is a similar concept to competence, may negate the negative impact of neuroticism on physical activity (Smith, Williams, O'Donnell, & McKechnie, 2017), and thus intervention aimed at improving self-efficacy may help people with high neuroticism become more physically active (Newsome, Kilpatrick, Mastrofini, & Wilson, 2021; Wilson & Rhodes, 2021).

Together, our results support the idea of physical activity as a habitual pattern that occurs independent of intention (Hagger, 2019). Dual-process theories suggest that a behavior may occur through a deliberative pathway, which includes cognitive effort and reflection, or through a non-conscious, automatic pathway (e.g. Strack & Deutsch, 2004). In the current study, the TPB constructs, and especially intention, captured a deliberate and reasoned process by which physical activity is enacted, while autonomous motivation and past physical activity indicated that more habitual and automatic processes are involved in physical activity. The direct association of past physical activity with current physical activity likely indicates habitual activity patterns (Hagger, 2019), and the direct association between autonomous motivation and physical activity indicates more spontaneous physical acitivty participation driven by self-determined motives (Hagger, Chatzisarantis, & Harris, 2016; Kaushal, Keith, Aguiñaga, & Hagger, 2020).

There are several possible explanations for our results. First, our assessment of physical activity was likely to capture habitual physical activity better than previous studies that used self-reported physical activity. We used hip-worn accelerometers to record all step-based activities occurring during the participants' wear time. Even though they are known to underestimate some types of physical activity, and cannot assess water-based activities because the devices are not waterproof, accelerometers can capture incidental lifestyle activities while self-reports typically focus on structured physical activity (Strath et al., 2013). These differences in physical activity measures may explain why only autonomous motivation and past behavior were associated with MVPA in the current study. People with high autonomous motivation towards physical activity are likely to enjoy physical activities, which may lead them to make spontaneous choices to be physically active in

Table 3
The moderator effect of personality traits on associations between psychological factors and MVPA.

Paths	Model excluding past MVPA			Model including past MVPA		
	Estimate	SE	*p*	Estimate	SE	*p*
Intention*Extraversion → MVPA	-.400	.260	.124	-.303	.304	.320
PBC*Extraversion → MVPA	-.536	.300	.074	-.290	.340	.393
Autonomous motivation*Extraversion → MVPA	-.037	.042	.368	-.052	.046	.261
Intention*Neuroticism → MVPA	.148	.311	.635	-.040	.377	.915
PBC* Neuroticism → MVPA	.220	.332	.507			
Autonomous motivation*Neuroticism → MVPA	.019	.045	.672	.029	.052	.582

Note. All moderator effects tested in separate models. Unstandardized estimates are presented. SE = Standard error of the standardized parameter estimate, MVPA = accelerometer-based moderate-to-vigorous leisure-time physical activity, PBC = Perceived behavioral control.

daily life (e.g. taking stairs instead of the elevator or walking to the store instead of driving a car). In addition, the influence of habit seems to be strongest with respect to active traveling (e.g. commuting by foot or bicycle; Gardner, de Bruijn, & Lally, 2011), and active commuting was included as leisure-time MVPA in the current study.

Second, some parts of previously found associations between certain psychological variables and physical activity may be explained by measurement bias. Common method biases occur when the relationships between variables are established due to measurement methods instead of the constructs themselves (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Our results are in line with those of previous studies showing that intention predicts self-reported physical activity but not accelerometer-based leisure-time physical activity among adolescents (Kalajas-Tilga et al., 2021) and intention predicts self-reported walking but not pedometer-measured step counts among young adults (Scott et al., 2007). These findings suggest that some shared variance between the TPB constructs and self-reported physical activity may be due to common method and reporting biases. For example, respondents' responses to psychological and behavioral constructs using the same survey methods may be similar, and there may be consistency in their responses to items presented consecutively in a questionnaire (Chan, Zhang, et al., 2020; Podsakoff et al., 2003). The lack of direct associations between the personality traits and physical activity in our study is also consistent with the findings of previous studies suggesting that extraversion in particular has a stronger association with self-reported than accelerometer-based physical activity (Kekäläinen, Laakkonen, et al., 2020; Wilson et al., 2015). This may also indicate that some shared variance between extraversion and self-reported physical activity could be explained by common method variance (Wilson et al., 2015).

Third, our measures had several limitations, which may explain our findings. In relation to personality traits, the use of the Eysenck Personality Inventory may explain the absence of associations between extraversion and MVPA, autonomous motivation and the TPB constructs. As indicated in a previous study, the positive association between extraversion and physical activity seems to be driven by the activity facet of extraversion (Rhodes, Courneya, & Jones, 2002). However, it was not possible to isolate these individual facets from the Eysenck Personality Inventory, so this could not be verified here. Moreover, the overall extraversion score obtained from the EPI seems to be more related to other facets of extraversion, such as sociability and assertiveness (Avia et al., 1995), which may have less relevance to physical activity (Kekäläinen, Terracciano, Sipilä, & Kokko, 2020). In relation to the lack of associations between the TPB constructs and MVPA, there may have been measurement correspondence issues. Ajzen (1991) suggested that psychological and behavioral measures need to correspond in terms of target, action, context, and time. In the present study, the temporal correspondence of the measures was not optimal: the self-report measures of the TPB variables referred to the following five weeks, but the accelerometers measured physical activity over a seven-day period and, on average, seven weeks after the completion of the questionnaire. In addition, the action correspondence was not optimal. The TPB questionnaire referred to leisure-time sports and/or vigorous physical activities. In contrast, the accelerometers captured leisure-time activities, including active commuting. Even relatively slow walking (approximately 4 km/h) was recorded as moderate physical activity; however, accelerometer thresholds for moderate activity do not take into account an individual's fitness level, so it is more difficult for individuals with low fitness levels to reach a target intensity than high-fit individuals (Kujala et al., 2017).

It is also important to bear in mind the other limitations of the present study. Given that the current data were not collected on a large, representative sample, they are not generalizable to other samples or the general population, so it is important to replicate these results in large adult samples that are demographically representative of the general population. The present sample was more educated and physically active compared to the average population and had relatively low scores for neuroticism compared with the ERMA baseline sample. The associations between personality traits and behavior may be therefore stronger in a sample with wider variations in personality traits and physical activity levels.

Even though we integrated several different constructs into a broader model, there are numerous other determinants of physical activity (e.g. self-efficacy, goal orientation and other personality traits from the FFM), and this may also have limited our study inferences. Notably, the absence of conscientiousness was a limitation of the current study. It is one of the most salient personality traits in relation to physical activity (Wilson & Dishman, 2015) and may moderate the relationship between intention and physical activity (Rhodes & Bruijn, 2013). Further, we did not include longitudinal measures of the other constructs in the model, such as autonomous motivation and the TPB variables. The inclusion of such measures could have enabled us to control for stability and changes in constructs as well as behavior over time.

This study has numerous strengths. We recruited a population-based cohort sample of middle-aged women. Most studies on this topic have been conducted in samples of adolescents or young adults, and it is important to study psychological predictors of physical activity in older populations. This is also the first study including effects of dispositional traits on physical activity alongside autonomous motivation and the TPB constructs in a single integrated model. The model offers important knowledge about how and why distal traits, such as neuroticism, are related to physical activity behavior. In addition, we used accelerometers to assess physical activity behavior and were able to use measures of past physical activity from four years prior making examination of long-term links between past and subsequent accelerometer-based physical activity possible.

In conclusion, the current results indicate that accelerometer-based MVPA occurs through habitual and impulsive routes rather than reasoned and deliberative routes. This has ramifications for interventions. Focusing on autonomy-supportive behavioral change techniques may help promote leisure-time physical activity among middle-aged women in this context. Individual differences, particularly low levels of neuroticism, may also be important. Accordingly, it may be useful to focus on enhancing self-efficacy and positive affect in people who score high in neuroticism (Wilson & Rhodes, 2021). Further research is warranted to replicate these results in different populations and to test whether these findings could be explained by differences between various physical activity assessment methods.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2022.102135.

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