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Daily dynamics of pro-environmental behaviors and eudaimonic well-being among adolescents

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ABSTRACT

Research shows that engaging in pro-environmental behaviors (PEBs) might enhance individuals' eudaimonic well-being, including meaning in life (ML) and closeness to others (CO). Despite adolescents' potential role in shaping sustainable societies and their vulnerability to environmental issues, existing literature has not adequately addressed this age group. Additionally, most of the extant research is built on cross-sectional studies, which target between-person differences and fail to capture within-person fluctuations occurring in everyday life. To address these gaps, this study explored the association of daily PEB with adolescents' daily ML and CO, and whether variations in habitual PEB levels are positively associated with variations in habitual levels of these two dimensions. Additionally, we examined the moderating role of self-transcendence values in the PEB-ML and PEB-CO relations. The study included 78 Italian adolescents (M_{Age} = 14.8, SD = .73, 29.5% females) from a larger cross-cultural research project. Participants completed a daily diary study, reporting their PEB, ML and CO once a day over 28 days. Using Dynamic Structural Equation Modeling, the results revealed a significant positive spillover effect from PEB to ML (B = .258; 95% CI: [.121, .402]), indicating that when individuals engaged in more PEB than usual, they experienced higher-than-usual ML the following day. On the other hand, the spillover from PEB to CO was non-significant (B = .099; 95% CI: [-.034, .226]). Moreover, no link was found between self-transcendence values and these spillover effects. These findings provide insights into possible short-term benefits of PEB for adolescents' ML and contribute to understanding the role of PEB in promoting youth well-being.

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1. Introduction

To address global environmental challenges, youth engagement in Pro-Environmental Behaviors (PEBs) - actions aimed at reducing environmental impact or improving environmental conditions (Kollmuss & Agyeman, 2002; Steg & Vlek, 2009) - is essential, given their crucial role in driving the transition to more sustainable lifestyles (United Nations General Assembly, 2015). During adolescence, individuals' behavior is shaped in ways that will affect future commitment to environmental protection (Bartolo, Palermiti, et al., 2023; Dahl et al., 2018). Moreover, as adolescents are especially vulnerable to the negative impacts of environmental issues on mental health and well-being (Pereira & Freire, 2021), investigating how PEBs can enhance their everyday well-being is especially relevant.

Often perceived as morally good acts, PEBs can foster Eudaimonic Well-Being (EWB), that refers to self-realization deriving from exercising one's best qualities to pursue virtuous life goals (Deci & Ryan, 2008; Ryan & Deci, 2001). Specifically, PEBs have been found to be positively associated with various dimensions of EWB (Carrero et al., 2020; Prati et al., 2017; Redondo et al., 2022) as outlined in Ryff and Singer's (2008) multidimensional model of psychological well-being. Among key dimensions during adolescence (Kroger, 2007) are meaning in life (ML), the perception of one's life as coherent, significant, and purposeful (Martela & Steger, 2016), and closeness to others (CO), the experience of warm, secure, and trusting relationships (Ryff & Singer, 2008).

Recent evidence has shown the immediate, short-term effects of PEB on young adults' EWB in everyday life. However, most studies have focused on older samples and on stable interindividual (between-person) differences, mostly employing cross-sectional designs. A deeper examination of intraindividual (within-person) processes is therefore needed to capture dynamic changes in behaviors and experiences over short-time periods (Hamaker et al., 2018; Kuper et al., 2021).

An ecologically valid alternative is intensive longitudinal data collected through Experience Sampling Methods (ESM; Hektner et al., 2007), which can offer insights into the immediate impact of PEBs on EWB in naturalistic contexts. This method also allows consideration of stable individual characteristics shaping daily relations (McNeish & Hamaker, 2020).

The present study extends previous research by investigating the day-to-day effect of PEBs on two distinct dimensions of EWB - ML and CO - in an adolescent sample using intensive longitudinal data. Moreover, given the critical role of values during adolescence (Bartolo, Servidio, et al., 2023), we explored the moderating role of Self-Transcendence Values (S-TRV), which prioritize the well-being of others and the natural world over personal interests (Schwartz, 1992), in the relation between PEB and ML/CO. Research indicates that among the values influencing PEB engagement, S-TRV are the strongest predictors of individuals' participation in PEBs (e.g., Steg, 2016). They are also relevant for fostering eudaimonic experiences of well-being, which emerge from acting in accordance with one's moral principles (Venhoeven et al., 2013). As PEBs may reflect one's self-transcendent orientation, this study aims to shed light on the role of S-TRV, as stable tendencies, in sustaining adolescents' motivation to engage in PEB and, in turn, in fostering ML and CO on a daily basis. To address these questions, we conducted a 28-day daily diary study (Bolger et al., 2003) with Italian adolescents to examine the day-to-day relations between PEB and EWB and whether S-TRV moderates these associations.

We employed a daily diary design with one assessment per day to allow adolescents sufficient time to engage in PEBs, reflect on their behaviors and well-being, and to maximize compliance by requiring only a single daily report of their experiences. Concerning PEBs, prior research indicates that these behaviors can vary across time and contexts (Guo et al., 2026; Prinzing, 2024). Daily diary methods are therefore well suited to capturing such within-person variability and the well-being experiences that accompany these behaviors (Bissing-Olson et al., 2013). This approach is particularly relevant for adolescents, as evidence on how PEBs are enacted in everyday contexts within this age group remains limited (Pereira et al., 2025). Studying PEBs in daily life helps clarify how adolescents act and feel in the face of environmental challenges and offers a more fine-grained view of their personal agency as everyday agents of change (Pereira & Freire, 2021). Importantly, adolescents may contribute to addressing environmental issues not only through formal civic engagement (e.g., activism) but also through frequent pro-environmental actions enacted in daily life. However, daily diaries do not permit the assessment of shorter-term effects, such as hours, which could be better captured through Ecological Momentary Assessments (EMA; Shiffman et al., 2008), namely multiple assessments per day, that may also yield a lower recall bias.

1.1. The relation among PEB, meaning in life and closeness to others

Individuals often ascribe personal or moral significance to PEBs, perceiving environmental protection as inherently good or morally right because it contributes to improved living conditions for both humans and non-human beings (Venhoeven et al., 2017). This is especially true in Western societies, which are most responsible for overconsumption and environmental degradation (Nielsen & Hofmann, 2021). Although PEBs may require personal effort, as they often involve changing habits or investing personal resources (Steg et al., 2014), such as eating more plant-based foods, purchasing sustainable products, or using greener means of transportation, they can also be self-rewarding (Venhoeven et al., 2017). Indeed, beyond providing pleasure or social approval (Steg, 2016), engaging in morally good acts can make individuals feel good about themselves and foster a sense of self-fulfillment (Venhoeven et al., 2013). In this vein, the literature has highlighted the co-benefits of PEBs (Prinzing, 2023), emphasizing positive non-environmental outcomes associated with these behaviors, including experiences of EWB (Zawadzki et al., 2020).

Considering ML, Martela and Steger (2016) propose that people strive to perceive their lives as predictable, significant, and directed. Among these dimensions, the facet of ML called significance - the experience that one's life is worthwhile, arises from an evaluation of one's actions in light of deeply held values and aspirations. Importantly, significance is closely linked to eudaimonic living, that is, living in accordance with one's moral principles. Attributing significance to one's actions can nurture self-worth and lay the foundations for a broader sense of life as meaningful (Martela & Steger, 2016). Moreover, Costin and Vignoles (2020) showed that significance is a stronger predictor of ML than coherence or purpose, as individuals tend to attribute meaning to their lives when they perceive that what they do has value for others and leaves a lasting positive impact. In this perspective, PEBs can be considered eudaimonic activities (Martela & Sheldon, 2019). The sense of meaningfulness is particularly strong when PEBs are perceived as conscious and self-endorsed choices, rather than imposed or automatic, because they express individuals' authentic will (Venhoeven et al., 2013, 2017).

Regarding CO, PEBs can also be perceived as acts of care, seen as collaborative efforts to preserve shared resources (Klein et al., 2022), contributing to a sense of connectedness to one's community or broader society (Carrero et al., 2020; Nelson et al., 2007). Engaging in PEBs can thus be viewed as a form of cooperation, solidarity, and belonging to a group committed to the common good (Carrero et al., 2020; Klein et al., 2022). However, as highlighted by Carrero et al. (2020), PEBs, particularly those enacted in the public sphere or that deviate from prevailing social norms, such as activism or purchasing sustainable products, can sometimes generate tension or conflict with close others, rather than enhancing positive relationships. In such cases, these behaviors may actually hinder CO, depending on how they are perceived and supported within one's social environment.

From a conceptual perspective, according to Self-Determination Theory (Deci & Ryan, 2000; Ryan & Deci, 2017), engaging in PEBs might foster ML and CO by satisfying basic psychological needs:

autonomy, competence, and relatedness. Autonomy concerns the experience of acting in accordance with one's will and volition, such that one's actions are perceived as congruent with and endorsed by the self (Ryan & Deci, 2006). As highlighted by Bandura's Social-Cognitive Theory (SCT; Bandura, 1986, 2001), individuals can proactively shape their environments by exercising personal agency (Caprara & Steca, 2007; Sawitri et al., 2015), such as setting goals, monitoring behavior, and self-evaluating one's conduct. This fosters both environmental protection and personal development (Bandura, 2001). Autonomously choosing to pursue virtuous goals, such as acting responsibly toward nature, can motivate actions aimed at environmental preservation (Cuadrado et al., 2023; Sawitri et al., 2015). In particular, perceiving one's behavior as self-directed can foster ML (Venhoeven et al., 2013) by making individuals perceive their choices as a reflection of their authenticity and being good persons rather than perceiving their behavioral choices as motivated by external rewards or coerced (Van der Werff et al., 2014; Venhoeven et al., 2017). Competence involves the experience of being capable and effective. In the context of PEBs, adolescents may experience competence through engaging in behaviors that require specific knowledge, skills, and problem-solving abilities (Vijaikis & Poškus, 2024). For example, knowing which plastic items are recyclable, or having the skills and information needed to write a letter to a policymaker about an environmental issue can foster a sense of competence by enabling informed and effective action (Cooke et al., 2016; Poškus, 2021). Since people are oriented to growth (Huta & Ryan, 2010), PEBs can ultimately serve to express one's best capacities, especially when challenging.

In this vein, PEBs enhance EWB (Venhoeven et al., 2013), particularly ML, which derives from experiencing a sense of mastery and accomplishment of relevant goals (Martela et al., 2024). Relatedness refers to a sense of belonging and cultivating positive relationships, which is something that people strongly value and is thus a source of ML (Martela et al., 2024). Moreover, as PEBs can foster the perception of contributing to collective well-being (Prati et al., 2017) and reflect the desire to be valued in society (Mac Donald & Staats, 2022), they can also satisfy the need for relatedness.

1.2. Relations among self-transcendence values, PEB, meaning in life and closeness to others

Although protecting the environment is widely considered a moral imperative (Nielsen & Hofmann, 2021), individuals differ in their motivation to engage in PEBs (Steg, 2016) and in their perception of these actions as inherently good or morally right (Venhoeven et al., 2013). These interpersonal differences are influenced by personal values, which serve as guiding principles in individuals' lives (Schwartz, 1992). Notably, S-TRV, comprising dimensions such as universalism, referring to concern for the welfare of all people and nature, and benevolence, referring to concern for the well-being of close others (Schwartz, 2012), and often conceptualized in environmental psychology as altruistic and biospheric values, are particularly relevant for PEB engagement (e.g., Stern & Dietz, 1994). People who endorse these values tend to show greater concern for others' well-being, including societal and environmental welfare (Venhoeven et al., 2016). Rather than being driven by hedonic motives such as pleasure, they are motivated by a sense of moral obligation, prioritizing collective benefits over personal gains like social approval or financial rewards. Moreover, since values fundamentally shape how individuals interpret and evaluate the outcomes of their actions, those with stronger S-TRV tend to prioritize the long-term, collective benefits of environmental engagement and to appraise its impact in terms of societal and ecological well-being rather than personal gain (Steg, 2016). These values also play a role in nurturing EWB, as individuals with stronger S-TRV are more likely to perceive PEBs as meaningful and self-rewarding (Venhoeven et al., 2013). Their engagement in PEBs is likely to reflect a genuine and deliberate commitment to doing good. In this way, these values can not only foster PEBs but also nurture personal fulfillment by aligning actions with deeply held principles (Huang et al., 2024; Venhoeven et al., 2013). According to the eudaimonic perspective of well-being (Huta & Ryan, 2010), living in accordance with one's moral goals is a key source of ML because values are standards used to evaluate one's actions and life as worthwhile. Notably, the significance facet of ML (Martela & Steger, 2016) aligns closely with S-TRV, as both reflect living responsibly through the pursuit of meaningful and virtuous endeavors. Because the attribution of significance to one's existence depends on a personal evaluation of what is important and valuable (Martela & Steger, 2016), individuals who endorse S-TRV are more likely to perceive their lives as meaningful and worthwhile when acting in accordance with these values, that is, when pursuing the welfare of others and the collective good, including through engagement in PEBs (Shin et al., 2022). Moreover, as they imply prioritizing others' interests, S-TRV are also linked to an increased sense of closeness to others (Hwang et al., 2019).

1.3. PEB, meaning in life and closeness to others during adolescence

Examining the relations between PEB, ML and CO in adolescents is essential for understanding whether and how engaging in acts of care toward the environment can promote key dimensions of well-being (Avedissian & Alayan, 2021; Damon et al., 2003; Krok, 2018) in this age group (Baumeister & Leary, 1995; Brouzos et al., 2016; Chue & Yeo, 2023; Kroger, 2007). This developmental stage is marked by the emergence of moral identity (Krettenauer, 2022) and values that shape attitudes, behaviors, and well-being (Bojanowska & Piotrowski, 2019; Liu et al., 2021; Ungvary et al., 2018). In this period, individuals adopt behaviors that can shape long-term habits and influence future well-being (Avedissian & Alayan, 2021; Damon et al., 2003), including PEBs (Bartolo, Servidio, et al., 2023; Ojala, 2022). Moreover, adolescence is often accompanied by declining well-being (López-Pérez & Zuffianò, 2021) and vulnerability to environmental issues on mental health (Becht et al., 2024; Gomez-Baya et al., 2020).

PEBs can be understood as a part of moral development, as they require prioritizing collective welfare over self-interest (Krettenauer, 2017; Nielsen & Hofmann, 2021; Sachdeva et al., 2015). While the perception of environmental protection as a moral obligation starts in childhood, this tends to change over time (Krettenauer, 2017; Otto et al., 2019). Adolescents show heightened moral sensitivity toward environmental issues, given their enhanced perspective-taking, abstract thinking and knowledge about societal issues (e.g., Eisenberg et al., 1995; Eisenberg et al., 2002), yet this does not always translate into strong environmental commitment (Olsson & Gericke, 2015; Zhang et al., 2023). They often struggle to perceive it as relevant to their immediate interests, especially due to strong desires for autonomy and peer status, leading to a lack of urgency regarding climate action (Thomaes et al., 2023; Yeager et al., 2018). In this context, studies showed a declining trend in adolescents' engagement with environmental issues and their adherence to values linked to social responsibility (Krettenauer et al., 2019, 2020). This phenomenon, often referred to as the “adolescent dip” (Olsson & Gericke, 2015), is characterized by weaker environmental attitudes and norms (Krettenauer, 2017), including lower belief in the importance of protecting nature from exploitation (Otto et al., 2019) and less concern about environmental issues compared to younger children and adults (Casaló & Escario, 2016; Zhang et al., 2023). This trend may be explained by developmental processes characteristic of adolescence, such as the pursuit of independence, socialization and identity exploration. These developmental tasks may make it difficult, under certain circumstances, to prioritize environmental concerns over needs for autonomy and social integration (Thomaes et al., 2023). Moreover, their environmental self-identity- the extent to which they see themselves as environmentally conscious (van der Werff et al., 2013) - is still under development (e.g., Crocetti, 2017). Due to increased susceptibility to peer influence and a tendency to challenge parental norms and values (Balundė & Perlaviciute, 2023), adolescents'

engagement in PEBs is shaped by whether such actions are supported by others and experienced as autonomous rather than imposed by adults (Collado et al., 2019; Koessler et al., 2022; Thomaes et al., 2023). Ongoing brain maturation further limits their ability to consider long-term consequences and adopt a future-oriented perspective (Pereira & Freire, 2021).

Indeed, they are highly sensitive to short-term rewards, which may lead them to view environmental protection as less personally relevant compared to their immediate autonomy and socialization goals. However, both dispositional and contextual factors play a role in determining adolescents' PEB. For instance, limited financial autonomy or parental control over environmental choices may hinder adolescents' perceived self-control over PEBs, thereby reducing their engagement (Thomaes et al., 2023). Moreover, given that adolescence is a critical period for conforming to social norms and integrating into the broader society (House et al., 2013; Thompson & Nelson, 2011), the extent to which PEBs are valued and practiced by close others, reflected in injunctive and descriptive norms, can either support or hinder adolescents' engagement in these behaviors. Notably, family and peers exert a strong influence, serving as key socializing agents in adolescents' development of a sense of moral obligation toward the environment (Collado et al., 2019). Moreover, emotional processes can influence their engagement, with high levels of worry and anxiety (Becht et al., 2024) or denial-based hope (Thomaes et al., 2023) can discourage PEB engagement (e.g., Ojala, 2011). Finally, values and self-identity can also play a role: adolescents who prioritize environmental protection and perceive it as central to their sense of self are generally more likely to engage in PEBs (Thomaes et al., 2023).

Despite these challenges, PEBs can offer adolescents valuable opportunities for personal growth, fostering a deeper sense of well-being beyond mere pleasure or material gains (Damon et al., 2003; Venhoeven et al., 2017). Consistent with the view that eudaimonic functioning is grounded in the satisfaction of basic psychological needs (Martela & Sheldon, 2019), we considered ML and CO as key indicators of adolescents' psychological adjustment and as fundamental for a successful transition to adulthood (Baumeister & Leary, 1995; Brouzos et al., 2016; Chue & Yeo, 2023). In particular, ML can play a crucial role in helping them explore their identity, nurture psychological well-being (Kroger, 2007) and commit to long-term goals, including caring for the common good (Damon et al., 2003). ML has been consistently identified as a protective factor against emotional instability, risky behaviors, and psychological distress in adolescents (Rathi & Rastogi, 2007). Adolescents can find meaning from various activities, including self-transcendent ones, namely acting toward a greater cause (Rathi & Rastogi, 2007). In this context, the meaningfulness attributed to PEBs can help adolescents perceive environmental challenges as important, and in turn buffer the adverse effects of environmental worry on their well-being (Ojala, 2005). ML reflects an intrapersonal dimension of EWB, arising from attributing personal meaning and significance to one's daily actions. We focused on the significance facet of meaning, as it captures adolescents' evaluation of life's worth in the present moment (Martela & Steger, 2016). Given that adolescence is a developmental period in which individuals are still forming their future orientation (Pereira & Freire, 2021), perceiving significance in daily activities may help them integrate present experiences into a broader sense of purpose that extends into the future. On the other hand, CO captures an interpersonal dimension of EWB, reflecting the importance of positive and supportive relationships in fulfilling the fundamental need for relatedness (Baumeister & Leary, 1995). CO is fundamental for social support, identity formation, and coping with stress (Chue & Yeo, 2023). Through engaging in PEBs, adolescents can enhance their sense of belonging and contribution to society (Berger & Andaur, 2022; Mac Donald & Staats, 2022; Vijaikis & Poškus, 2024). From the perspective of Positive Youth Development (PYD; Lerner et al., 2015), adolescents possess enhanced resources to positively contribute to their surroundings and promote their healthy functioning. In this context, PEBs can be seen as positive developmental experiences (Benson & Scales, 2009; Lerner et al., 2002) and a form of youth civic engagement, defined as active participation in activities aimed at addressing societal issues for the common good and community well-being (Krettenauer, 2017; Wray-Lake et al., 2017). Civic engagement can foster well-being (Damon et al., 2003; Malin et al., 2015; Wray-Lake et al., 2019) by satisfying basic needs, as shown in a recent daily diary study by Wray-Lake et al. (2019). Similarly, research by Vijaikis and Poškus (2024) showed that engagement in PEBs promoted adolescents' subjective well-being through the fulfillment of competence and autonomy needs.

These needs are particularly relevant during adolescence, a period marked by the pursuit of autonomy and active identity exploration (Kemper et al., 2024). Regarding competence, as emphasized in Social-Cognitive Theory (SCT; Bandura, 2001), effectively influencing both physical and social environments (Koskela & Paloniemi, 2023; Sawitri et al., 2015), can strengthen adolescents' commitment to meaningful life goals and challenges, a core element of EWB (Salavera et al., 2020; Venhoeven et al., 2013). Concerning relatedness, adolescents increasingly prioritize nurturing personal relationships and engaging more deeply in community activities (Arnett, 2000; Kemper et al., 2024). Thus, PEBs can enhance their sense of belonging and contribution to society (Berger & Andaur, 2022; Mac Donald & Staats, 2022; Vijaikis & Poškus, 2024).

1.4. Literature review and research gap

There is substantial evidence on the positive association between PEB and EWB (e.g., Carrero et al., 2020; Shin et al., 2022; Venhoeven et al., 2016). However, limited attention has been paid to adolescents (Balundė et al., 2020), with much focus on older populations. Considering cross-sectional evidence, a recent study by Bartolo, Servidio, et al. (2023) on a sample of 1925 Italian adolescents aged 14–20 (Mean Age = 16 years), found that PEBs like recycling and conserving water was positively associated with various dimensions of EWB, including connectedness with others and experiencing meaningful social engagement. In older samples, Carrero et al. (2020) found positive relations between PEB and various dimensions of psychological well-being, reflecting eudaimonic well-being, in Spanish young adults (Mean Age = 18). Notably, PEB was positively related to purpose in life, whereas no significant associations emerged with experiencing positive relationships. Furthermore, a meta-analysis by Zawadzki et al. (2020) found that the positive association between PEBs and well-being was strong for meaning-related aspects such as intentional purchase behaviors and eudaimonic happiness, which reflect individuals' perceptions of their lives as meaningful. In an experimental study with 545 participants, mostly young adults (M_{Age} = 19 years), Prinzing (2024) found that daily PEBs increased meaning in life.

Regarding long-term longitudinal research, a two-wave study with a sample of 369 university students conducted by Redondo et al. (2022) found small but positive correlations between PEB, meaning in life and positive relations, across two time points. Similarly, Prati et al. (2017) showed that PEB predicted subsequent social well-being (i.e., nurturing positive relationships) in 298 Italian young adults across two time points. In this study, the authors also examined the reverse path, finding that higher experiences of positive relationships predicted subsequent PEB. The reciprocal association between these variables remains largely understudied, as most research has focused on the effect of PEB on well-being (Redondo et al., 2022). However, clarifying this reciprocal effect may help elucidate how living in line with one's moral aspirations, experiencing one's life as significant, and cultivating close relationships can foster acts of environmental protection. As discussed by Prati et al. (2017), individuals who experience higher EWB may be more motivated to pursue non-materialistic and other-oriented goals, such as contributing to one's community, reflecting a motivation to reciprocate society's care toward themselves. Moreover, ML (notably, significance) may sustain people's motivation to pursue relevant courses of action (Martela

& Steger, 2016).

Considering intensive longitudinal research, a daily diary study by Caldaroni et al. (2025) employing within-person manipulations of PEB examined its causal impact on EWB in a sample of Italian young adults (M_{Age} = 24 years) over a 21-day period, revealing a significant and positive effect of PEB on meaning in life and closeness to others. Richter and Hunecke (2022) reported positive within-person and between-person associations between PEB and meaning in life in 183 adults followed over 7 days.

Regarding the role of S-TRV, research has examined eudaimonic values defined as the tendency to prioritize actions promoting autonomy, excellence, and self-actualization (Winkler-Schor et al., 2020); and eudaimonic motivations, namely the pursuit of meaning in life and self-fulfillment derived from developing the best in oneself and exercising virtues like generosity, courage, and kindness (Huta & Ryan, 2010), including a sense of responsibility toward the environment (Zhou et al., 2021). For instance, Winkler-Schor et al. (2020) found that altruistic, biospheric, and eudaimonic values predicted pro-environmental intentions in 667 adults. Polisetty et al. (2024) showed eudaimonic motivations predicted green purchase intentions in 479 individuals, mainly young adults.

Existing research on the relationship between PEB and well-being in adolescence highlights several key gaps. First, most studies have focused on hedonic well-being, leaving the eudaimonic dimension relatively underexplored, particularly among adolescents. Second, despite some evidence in young adults, there is a significant lack of evidence on the immediate and short-term effects of PEBs on adolescents' EWB in daily life, as most research relies on cross-sectional designs that emphasize between-person differences (Richter & Hunecke, 2022). Investigating the short-term benefits of engaging in PEBs for adolescents' well-being is particularly important for sustaining their motivation, given that their future-oriented thinking is still developing and they are particularly sensitive to immediate rewards (Pereira & Freire, 2021). Experiencing personal and immediate benefits may therefore help adolescents perceive PEBs as consistent with their core motives, making pro-environmental engagement more appealing and intrinsically rewarding in the short term (Thomaes et al., 2023). Examining intra-individual (within-person) fluctuations is crucial to understanding whether performing more PEBs than usual on a given day can lead to higher-than-usual ML/CO. Our study goes beyond previous research (Caldaroni et al., 2025; Richter & Hunecke, 2022) by examining day-to-day relations between these variables in an adolescent sample and by distinguishing between two key dimensions of EWB, ML and CO. In line with Carrero et al. (2020), differentiating among the various components of psychological well-being is crucial to better clarify their associations with PEBs, as these relationships may vary when using composite measures of well-being rather than examining discrete dimensions.

1.5. The present study

Focusing on daily fluctuations in PEB and ML/CO in adolescents' everyday life, particularly regarding frequently performed behaviors such as recycling or conserving energy, the aim of the present study was to explore the daily relations between PEBs and these two facets of EWB, and the role of S-TRV as person-level characteristics in modulating these temporal dynamics. Precisely, in the present study, we employed daily diary data collected among Italian adolescents to assess their levels of PEBs, ML and CO once a day over 28 days.

We explored: (1) the reciprocal, day-to-day relations between PEBs and ML/CO (i.e., spillover effects) and their autoregressive effects over time (i.e., carryovers); (2) the moderating role of S-TRV in such temporal dynamics. In more detail.

1. (a) as a main aim, whether engaging in more PEBs than usual (with respect to one's personal average level) on a given day would result in higher-than-usual levels of ML/CO on the following day. Building on previous literature (e.g., Caldaroni et al., 2025), we hypothesized a positive spillover effect from PEB to both ML and CO. Additionally, considering that eudaimonic motivations may sustain pro-environmental action (e.g., Martela & Steger, 2016; Shin et al., 2022; Venhoeven et al., 2013), and in line with Prati et al. (2017)'s findings, we also examined the reverse spillover from ML/CO to PEB, hypothesizing that positive deviations in well-being could predict higher-than-usual levels of PEB. (b) As a secondary aim, we explored whether higher than usual PEBs/well-being facets predicted higher than usual levels of the same variable on subsequent days (carryovers). We expected positive carryover effects for both PEB and ML/CO (Gregori et al., 2024; Nilsson et al., 2017).
2. Considering the positive role of S-TRV for both PEB and EWB (Venhoeven et al., 2013), we explored the presence of a cross-level interaction between S-TRV as a stable, between-person characteristic and the spillover effect from PEB to ML/CO. We hypothesized that the within-person association between PEB and ML/CO would be amplified by these values (Venhoeven et al., 2013), namely that in individuals who assign more importance to collective interest, engaging in more pro-environmental actions than usual is associated with an enhanced experience of meaning in life and closeness to others. Additionally, although we did not have a priori hypotheses, we also considered the possibility that S-TRV might moderate the strength of the reverse spillover (from ML/CO to PEBs) and carryover effects for both PEBs and ML/CO.

2. Materials and methods

The sample was composed of 78 Italian adolescents (ages ranging from 14 to 17 years, M_{Age} = 14.77, SD = .73, 29.5% females), drawn from a larger intensive longitudinal study investigating factors promoting prosocial behavior, well-being, and pro-environmental behavior, with an emphasis on empathy-related responding. For the sample size, we followed the methodological recommendations of Maas and Hox (2005) for multilevel research, aiming to recruit at least 50 participants at the between-person level, while also considering the study's financial constraints. The gender distribution of our sample reflects the demographic composition of the Italian scientific high school ("liceo scientifico") where data were collected, which typically enrolls a higher proportion of male than female students. Although this study shares some methodological similarities with Caldaroni et al. (2025), that work is part of a different intensive longitudinal project investigating prosocial and pro-environmental behaviors, emotion regulation, and well-being in young adults. Moreover, in that study, participants received daily prompts to engage in PEBs, which served as an experimental manipulation to test the putative causal effect of PEB on EWB. The study, approved by the ethics committee of the author's institution [Sapienza University of Rome], formed part of a broader cross-cultural project exploring cultural variation in empathy and sympathy across four countries: Scotland, Chile, Iceland, and Italy. Data were collected between April and May 2024. At present, data are available only for the Italian sample. Participants were recruited from an Italian high school in the metropolitan city of Rome. The sample was composed by 84 students, 6 of whom did not participate in the daily diary study, so they were excluded from the analyses. The study was structured as follows: Before the study began, research assistants contacted the school principal and the two teachers who collaborated on the project. All participants and their families were informed about the voluntary and anonymous nature of the study. Additionally, the purpose of the research and other relevant details were communicated by teachers beforehand and supported by the researchers through written material describing the types of daily behaviors and experiences assessed, including PEBs. An email address was provided at the end of the questionnaire for participants to address any questions or concerns. After obtaining informed parental consent, participants were supported by

research assistants in downloading the GDPR-compliant experience sampling app (i.e., m-Path) and completing a baseline questionnaire during regular school hours, using the Qualtrics platform, which was also GDPR-compliant.

This initial survey collected socio-demographic information and assessed various personality measures, including S-TRV. After one week, researchers instructed participants about the daily diary phase of the study. For 28 days, they were sent online daily diaries to their smartphones once every 24 h, between 8:00 p.m. and 11:59 p.m., with reminder notifications after 90 min for any missed surveys. Participants had a 4-h window to complete each daily survey before it expired. Each day, participants rated the intensity of their PEB and their EWB. As a token of appreciation for their time, participants were given a €25 bookshop gift card for completing more than 75%.

Of the total 2184 possible observations (78 participants x 28 days), 1591 were completed across the 28 days, corresponding to a compliance rate of 73% (1591/2184). The retention rate was moderately low, with 33.2% (n = 26) of the participants providing data for at least 23 days. In detail, 33.3% (n = 26) of participants provided data for 10 or fewer days, 29.5% (n = 23) answered between 11 and 20 daily diaries, and 37% (n = 29) answered between 21 and 28 daily diaries. 6.4% of participants completed 28 daily diaries (n = 5).

2.1. Measures

PEB (Daily diary; within-person level). Participants reported their daily PEB using four items adapted from Menardo et al. (2020); Tabernero and Hernández (2011), and Collado et al. (2019). The four items assessed plastic consumption, energy conservation, encouraging others to engage in PEBs and recycling. Preceded by "Today", they were: "Have you reduced your plastic consumption?; have you reduced the consumption of electricity? have you motivated others to take more care of the environment? have you recycled?". Participants answered on a five-point Likert scale, ranging from 1 = "Not at all" to 5 = "Extremely." The average score of the four items was used for analysis. Reliability was assessed using multilevel Omega (Lai, 2021) for momentary measures nested within participants. The internal consistency estimates for the four items were ω = .54 on the within-person level and ω = .78 on the between-person level, respectively. The low internal consistency of the PEB construct may stem from its inherent heterogeneity, as it includes a diverse range of behaviors (Lange, 2024). Following Brose et al. (2020), PEB can be viewed as a formative construct, a composite of distinct component variables (Edwards & Bagozzi, 2000), for which high internal consistency is not necessarily required. A similar line of reasoning applies to the construct of EWB, which, according to Ryff and Singer's (2008) model, comprises distinct dimensions.

ML (Daily diary; within-person level). It was assessed using a single item (Negri et al., 2020): "Today I understood what gives value to my life". Participants answered on a five-point Likert scale (1 = "Strongly disagree"; 5 = "Strongly agree").

CO (Daily diary; within-person level). It was measured through one item adapted from Ryff and Keyes (1995). The item was: "Today I had affectionate and trusting relationships with others". Participants answered on a five-point Likert scale (1 = "Strongly disagree"; 5 = "Strongly agree").

As participants completed a larger daily survey assessing well-being and empathic responses, single-item measures were employed to reduce participant burden and maintain data quality, a solution often used in experience sampling research (Gabriel et al., 2019). The selection of the specific items was guided by theoretical considerations aimed at capturing the most salient aspects of each construct at the daily level in an adolescent sample. Specifically, to capture the significance facet of ML, we selected the item from the Presence of Meaning subdimension of the Italian version of the Meaning in Life Questionnaire (Negri et al., 2020) that best captures adolescents' perceived understanding of what gives their lives value. For CO, we selected the item from the *Positive Relationships* dimension of Ryff and Keyes' (1995) Psychological Well-being Scale that most directly reflects the subjective experience of feeling close to others.

S-TRV (Baseline, Between-person level). Self-transcendence values were assessed as a baseline measure using five items of the Portrait Values Questionnaire (PVQ-21; Capanna et al., 2005; Schwartz, 2003), which evaluates values based on brief descriptions of a person's goals, aspirations, or desires derived from Schwartz's theory of values (e.g., "It's very important to me to help the people around me. I want to care for their well-being"; "I strongly believe that people should care for nature. Looking after the environment is important to me"). We assessed values in the domains of benevolence and universalism, which together constitute the self-transcendence dimension, as outlined in Schwartz's (1992) circumplex model. Participants answered on a seven-point Likert scale ranging from "Not like me at all" (1) to "Very much like me" (7). An average score of the self-transcendence items was calculated for analysis. Internal consistency (McDonald's ω) was .70.

2.2. Data analytic approach

We used DSEM (Asparouhov et al., 2018), a statistical technique well suited to analyze high-density data from multiple individuals. The model used in these analyses is a two-level DSEM, which combines basic time series models with multilevel structural equation modeling. For each of the repeatedly assessed variables, it consists of regressing a vector of observations at occasion t on the vector of observations at the preceding time occasion (t-1) to capture the temporal dependencies in the variable. The DSEM approach allows for decomposing the data into a within-person and a between-person component, specifically to examine dynamic intraindividual variability in the constructs of interest - that is, within-person fluctuations or deviations from one's mean occurring over time - while accounting for stable between-person differences in these variables (Hamaker et al., 2018). DSEM allows modeling of two time-lagged effects, the spillover and carryover effects. The first one captures the predictive relation of a variable on another measured at the previous time point. The carryover effects are autoregressive parameters that model the time-lagged effect of a variable on itself, reflecting the persistence or inertia over time, namely, how slowly a person returns to his/her equilibrium.

For the first aim of the study, we employed a two-level DSEM (as depicted in Fig. 1) and estimated two separate models, one including ML (Model 1) and one CO (Model 2).

In Model 1, reciprocal lagged associations between PEB and ML (spillover effects) were modeled, as were day-to-day autoregressive effects of PEB and ML, at time t-1 on PEB/ML on the following time occasion (t). The four effects (two autoregressive effects and two spillover effects) were treated as random slopes, that is, they were allowed to vary at the between-person level to capture the between-person differences in their strength. Additionally, we included the time-specific within-person correlation among the residual terms of the variables, reflecting their simultaneous, occasion-specific associations. Random intercepts of PEB and ML (i.e., the person's average scores in the variables across the twenty-eight days) were estimated. The same model structure and estimation procedure were applied to Model 2.

For the second aim of the study, we included S-TRV as a between-person predictor to explore its moderating role in the relation between day-to-day associations of PEB and ML (Model 3) and for PEB and CO (Model 4). Participants' gender was added as a covariate in these models.

The models were estimated using MPlus version 8.11 (Muthén & Muthén, 1998-2019) with Bayesian parameter estimation, which is well-suited for handling a large number of random effects (Hamaker et al., 2018). The estimation process employed two Markov Chain Monte Carlo (MCMC) chains, utilizing the default MPlus prior settings. A thinning factor of 10 was applied to reduce autocorrelations in the posterior distribution. To our knowledge, there are no specific

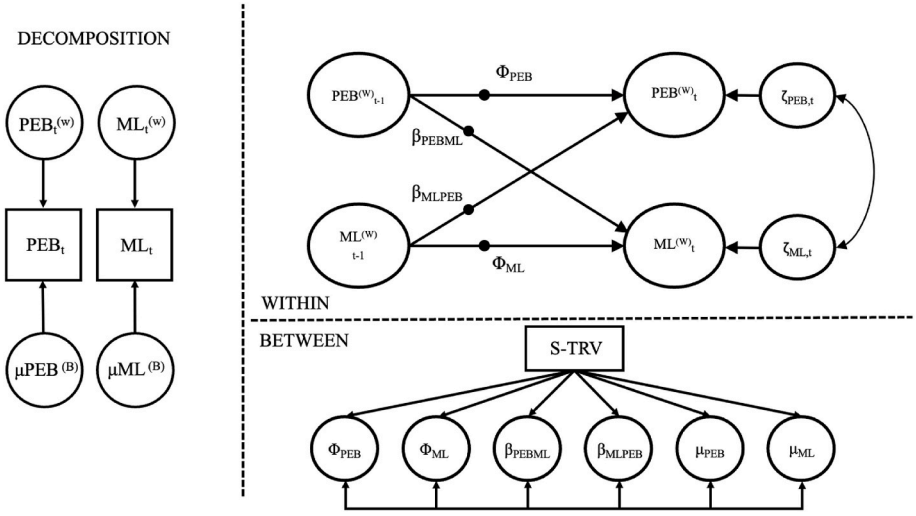

Fig. 1. *Graphical representation of Dynamic Structural Equation Modeling for Pro-environmental behavior, Meaning in Life and Self-transcendence values.*
Note. The left section represents the decomposition of each daily diary assessment into a within-person component (time-varying) and a between-person component (time-invariant), reflecting participants' average levels (μs) of PEB and ML. The bottom part of the figure represents S-TRV as a predictor of the intercepts of the variables and the random effects, corresponding to the solid black circles in the within-person level model. β_{PEBML} = spillover effect from PEB to ML; and β_{MLPEB} = spillover effect from ML to PEB; Φ_{PEB} = carryover effect of PEB; Φ_{ML} = carryover effect of ML. Gender was included as an additional predictor of the six random effects, but it is not depicted in the figure.

guidelines for choosing a thinning factor. The thinning factor primarily serves to reduce autocorrelation in the parameter estimates of the MCMC chains. Once model convergence is established (as was the case in our model), further increasing the thinning factor is not expected to change the results. The factor was chosen based on previous experience with these types of models and it was not further increased because the model had converged. Lagged effects were estimated for a 1-day interval using the TINTERVAL option in MPlus (McNeish & Hamaker, 2020). Statistical significance was determined using 95% credible intervals (95% CI; McNeish & MacKinnon, 2022), with effects deemed significant if their credible intervals excluded zero. To ensure robustness, the analyses were repeated across 1,000, 3,000, and 5000 iterations. In the results section, we only report the results of the 5000 iterations model. Model convergence was assessed through Potential Scale Reduction (PSR) values near 1, as well as by visual inspection of trace and autocorrelation plots from the posterior distribution, to identify potential irregularities (Asparouhov & Muthén, 2023; Hamaker et al., 2018).

3. Results

3.1. Descriptive analyses and bivariate associations

Participants reported moderate average levels for both PEB (M = 3.163; SD = .879), ML (M = 3.159; SD = 1.049) and CO (M = 3.485; SD = .952), calculated by averaging participants' scores across the 28 daily diaries. All measures showed variation both within and between individuals. The ICCs were .677 for PEB, .310 for ML and .293 for CO, indicating 67.7%, 31.0%, and 29.3% respectively as the proportion of variance resulting from stable individual differences at the between-person level. The remaining variance, 32% for PEB, 69% for ML, and 71% for CO was due to daily fluctuations within individuals. The fluctuations between PEB and ML ($r = .148$, $p < .001$) and between PEB and CO (r = .069, p = .026) were positively and significantly correlated. Similarly, at the between-person level, there was a positive and significant correlation between PEB and ML ($r = .126$, $p < .001$), and PEB and CO ($r = .307$, $p < .001$), suggesting that the stable, trait-like components of PEB and EWB over the study period were positively associated. At the between-person level, S-TRV ($M = 4.625$, $SD = .674$) was positively correlated with both PEB ($r = .287$, $p = .012$), ML ($r = .258$, $p = .024$) and CO ($r = .225$, $p = .049$).

3.2. Two-level DSEM for PEB and ML

The DSEM model converged successfully, as confirmed by a maximal PSR value of 1.001.[1] Additionally, a visual inspection of the trace and autocorrelation plots showed no irregularities. In Table 1, we reported the unstandardized fixed and random effects with their 95% credible intervals, and the within-person standardized parameter estimates.

With regards to the spillover effects, we found a significant and positive spillover effect from $PEB_{i,t-1}$ to $ML_{i,t}$, as indicated by the unstandardized estimate for the fixed effect (B = 0.258; 95% CI: [.121, .402]). This means that higher-than-usual levels of ML on a day were positively predicted by higher-than-usual levels of PEB on the previous day. The standardized effect was β = .165; 95% CI: [.085, .245], showing that an increase of one person-specific standard deviation in PEB on a day was associated with an average increase of .165 person-specific standard deviations in ML the following day. In contrast, the reverse spillover effect from $ML_{i,t-1}$ to $PEB_{i,t}$ was non-significant (B = .045; 95% CI: [-.007, .094]).

With regards to the carryover effects, we also found positive and significant carryover effects for both PEB (B = .473; 95% CI: [.354, .584]) and ML (B = .255; 95% CI: [.162, .346]). The standardized results for the carryover effects for PEB and ML were β = .458; 95% CI: [.375, .543]) and β = .253; 95% CI: [.170, .330], respectively. Finally, results also showed a positive within-person correlation between the residual terms of PEB and ML ($r = .113$; 95% CI: [.051, .179]), indicating that days with more PEB tended to be days on which ML was also higher than usual, even after accounting for the effects of PEB and ML on the previous day.

At the between-person level, we observed significant between-person variability in the spillover and carryover effects. In particular, the random slope variance for the spillover effect from $PEB_{i,t-1}$ to $ML_{i,t}$, was .032, 95% CI [.002, .151], with the SD of the random slope being approximately .69 times as large as the average fixed effect. This suggests a moderate between-person variability in the strength of such a spillover effect (Bolger et al., 2019). Similarly, there was small to

[1] For completeness, we report in the supplementary materials the analyses of the models including EWB that were part of the original version of the manuscript. These materials are available at the following OSF: link:

Table 1
Results of the Two-part DSEM Model including PEB and ML (Model 1). Unstandardized and standardized within-person effects and correlation.

Parameters	Fixed effects (means)			Random effects (variances)			Standardized within-person effects		
	95% CI			95% CI			95% CI		
	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
PEB intercept	3.186[a]	2.996	3.361	.395[a]	.241	.653	-	-	-
ML intercept	3.175[a]	3.025	3.319	.241[a]	.135	.402	-	-	-
Spillover effects									
$PEB_{t-1} \rightarrow ML_t$	.258[a]	.121	.402	.032[a]	.002	.151	.165[a]	.085	.245
$ML_{t-1} \rightarrow PEB_t$	.045	−.007	.094	.010[a]	.001	.033	.067	−.001	.134
Carryover effects									
$PEB_{t-1} \rightarrow PEB_t$	.473[a]	.354	.584	.093[a]	.053	.163	.458[a]	.375	.543
$ML_{t-1} \rightarrow ML_t$	.255[a]	.162	.346	.035[a]	.006	.089	.253[a]	.170	.330
Within-person correlation									
$PEB_t \leftrightarrow ML_t$	-	-	-	-	-	-	.113[a]	.051	.179

Note. DSEM = dynamic structural equation model; CI = 95% credible intervals; PEB = pro-environmental behavior; ML = Meaning in Life.
[a] Credible interval did not include zero.

moderate between-person variability in the carryover effects. Specifically, the random slope variance for the carryover effect of PEB was .093, 95% CI [.053, .163], with the SD of the random slope being .64 times the average fixed effect. For the carryover of ML, the random slope variance was .035, 95% CI [.006, .089], with the SD approximately .73 times as large as the average fixed effect. Taken together, these results indicate moderate heterogeneity: participants differed in how strongly changes in PEB on one day predicted next-day changes in ML, and in the extent to which PEB and ML persisted from day to day.

3.3. Two-level DSEM for PEB and CO

Model 2 converged successfully (PSR = 1.005), with trace and autocorrelation plots showing no irregularities. Table 2 reports the unstandardized fixed and random effects (95% CIs) and the standardized within-person estimates.

Regarding the spillover effects, we found a non-significant spillover effect from $PEB_{i,t-1}$ to $CO_{i,t}$ (B = .099; 95% CI: [-.034, .226]) and from $CO_{i,t-1}$ to $PEB_{i,t}$ (B = .002; 95% CI: [-.049, .050]).

Conversely, we found positive and significant carryover effects for both PEB (B = .491; 95% CI: [.371, .603]) and CO (B = .203; 95% CI: [.127, .286]). The standardized results for the carryover effects for PEB and CO were β = .480; 95% CI: [.385, .564]) and β = .203; 95% CI: [.135, .274], respectively. We also found a positive within-person correlation between the residual terms of PEB and CO (r = .068; 95% CI: [.006, .130]), indicating that days with more PEB tended to be days on which CO was also higher than usual.

At the between-person level, we observed small to moderate between-person variability in the carryover effects. Specifically, the random slope variance for the carryover effect of PEB was .096, 95% CI [.055, .164], with the SD of the random slope being .63 times the average fixed effect. For the carryover of CO, the random slope variance was .018, 95% CI [.002, .063], with the SD approximately .66 times as large as the average fixed effect. In summary, the results indicated moderate heterogeneity, suggesting that individuals varied in how these behaviors and experiences carried over from one day to the next.

3.4. Two-level DSEM with S-TRV as a between-person predictor

Model 3 with PEB and ML including S-TRV as a between-person predictor and gender as a covariate demonstrated satisfactory PSR, with a maximum value of 1.006. Additionally, the trace and autocorrelation plots revealed no irregularities. No significant cross-level interaction emerged between S-TRV and the spillover and carryover effects, while controlling for gender (see Table 3). Instead, the model revealed that S-TRV predicted positively the intercept (i.e., the mean) of PEB (B = .351, 95% CI [.085, .615]) and ML (B = .241, 95% CI [.018, .477]), indicating that individuals with higher levels of S-TRV reported higher levels of PEB and ML across the 28 days.

For the corresponding model including PEB and CO (Model 4), convergence was satisfactory (maximum PSR = 1.003), and the trace and autocorrelation plots showed no irregularities. No significant cross-level interactions were found between S-TRV and the spillover or carryover effects when controlling for gender (see Table 4). However, S-TRV positively predicted the intercept of PEB (B = .390, 95% CI [.129, .650]) and CO (B = .247, 95% CI [.039, .447]), indicating that individuals higher in S-TRV reported greater average levels of PEB and CO across the 28 days.

To further explore whether gender affected the strength of the spillover and carryover effects, we re-estimated the model including

Table 2
Results of the Two-part DSEM Model including PEB and CO (Model 2). Unstandardized and standardized within-person effects and correlation.

Parameters	Fixed effects (means)			Random effects (variances)			Standardized within-person effects		
	95% CI			95% CI			95% CI		
	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
PEB intercept	3.182[a]	3.003	3.359	.380[a]	.239	.622	-	-	-
CO intercept	3.491[a]	3.362	3.629	.226[a]	.138	.367	-	-	-
Spillover effects									
$PEB_{t-1} \rightarrow CO_t$	.099	−.034	.226	.047[a]	.007	.142	.074	−.013	.153
$CO_{t-1} \rightarrow PEB_t$	.002	−.049	.050	.005[a]	.001	.021	.003	−.066	.067
Carryover effects									
$PEB_{t-1} \rightarrow PEB_t$	.491[a]	.371	.603	.096[a]	.055	.164	.480[a]	.385	.564
$CO_{t-1} \rightarrow CO_t$	.203[a]	.127	.286	.018[a]	.002	.063	.203[a]	.135	.274
Within-person correlation									
$PEB_t \leftrightarrow CO_t$	-	-	-	-	-	-	.068[a]	.006	.130

Note. DSEM = dynamic structural equation model; CI = 95% credible intervals; PEB = Pro-environmental behavior; CO = Closeness to others.
[a] Credible interval did not include zero.

Table 3
DSEM model for PEB and ML at 5000 iterations with Self-transcendence Values as a between-person predictor and gender as a covariate (Model 3).

Between-Level Unstandardized Estimates			
Parameters	95% CI		
	Estimate	Lower	Upper
Cross-level interaction with S-TRV			
S-TRV → Phi1	.002	−.157	.171
S-TRV → Phi2	−.027	−.179	.124
S-TRV → Beta1	.081	−.001	.165
S-TRV → Beta2	−.018	−.229	.195
S-TRV → PEB	.351[a]	.085	.615
S-TRV → ML	.241[a]	.018	.477

Note. DSEM = dynamic structural equation modeling; CI = 95% credible intervals; S-TRV = Self-transcendence values; PEB = Pro-environmental behavior; ML = Meaning in life; Phi1 = carryover effect of PEB; Phi2 = carryover effect of ML; Beta1 = spill-over effect from ML to PEB; Beta2 = spill-over effect from PEB to ML.
[a] Credible interval did not include zero.

Table 4
DSEM model for PEB and CO at 5000 iterations with Self-transcendence Values as a between-person predictor and gender as a covariate (Model 4).

Between-Level Unstandardized Estimates			
Parameters	95% CI		
	Estimate	Lower	Upper
Cross-level interaction with S-TRV			
S-TRV → Phi1	.018	−.148	.183
S-TRV → Phi2	−.018	−.153	.120
S-TRV → Beta1	.006	−.080	.093
S-TRV → Beta2	.014	−.183	.220
S-TRV → PEB	.390[a]	.129	.650
S-TRV → CO	.247[a]	.039	.447

Note. DSEM = dynamic structural equation modeling; CI = 95% credible intervals; S-TRV = Self-transcendence values; PEB = Pro-environmental behavior; CO = Closeness to others; Phi1 = carryover effect of PEB; Phi2 = carryover effect of CO; Beta1 = spill-over effect from CO to PEB; Beta2 = spill-over effect from PEB to CO.
[a] Credible interval did not include zero.

only gender as a between-person covariate. No significant cross-level interaction effects were found, either for ML and CO.

4. Discussion

This study aimed to advance knowledge of within-person processes occurring in adolescents' everyday lives, examining the hypothesized positive effect of daily engagement in PEB on daily ML and CO, as well as the moderating role of S-TRV in shaping these temporal dynamics. The study employed a sample of Italian adolescents followed over a four-week period and analyzed the data using DSEM (Hamaker et al., 2018) to model spillover and carryover effects, distinguishing between within-person and between-person variability. Moreover, it considered S-TRV as a between-level predictor.

The findings partially supported the first hypothesis of the study. At the within-person level, results revealed a positive and significant spillover effect from PEB to ML, whereas they showed a non-significant spillover from PEB to CO (Models 1 and 2). That is, positive deviations from an individual's mean level of PEB over the four weeks were only associated with higher-than-usual levels of ML from one day to another. These results suggest that engaging in pro-environmental acts more than usual in daily life might result in immediate benefits for adolescents, fostering a sense of ML. Indeed, given that PEBs often represent moral behaviors, including for adolescents who are aware and sensitive to the importance of environmental issues (Krettenauer, 2017), acts of environmental protection can be experienced as contributing to something larger than the self, which, in turn, can enrich one's life with a sense of meaning (Rathi & Rastogi, 2007). Moreover, PEBs may represent eudaimonic activities that reflect a responsible way of living, as evidenced by numerous studies (see, for example, Carrero et al., 2020). As such, they can contribute to experiencing life as meaningful and significant (Martela & Steger, 2016). In this vein, PEBs may be inherently motivating, as they satisfy a person's basic human needs, as evidenced by previous studies (e.g., Vijaikis & Poškus, 2024; Wray-Lake et al., 2019).

Considering adolescents' autonomy need, from an SCT perspective (Bandura, 2001; Sawitri et al., 2015), PEBs may provide opportunities in everyday life to adopt an agentic role in addressing environmental challenges. The resulting self-fulfilling experiences can reflect adolescents' self-endorsed choices to pursue meaningful goals as they seek autonomy from their families while exploring their identities and values (Inglehart, 1978; Kemper et al., 2024; Krettenauer, 2022). In line with this, Venhoeven et al. (2013) suggest that when PEBs are personally challenging or require effort, they are more strongly associated with EWB, as they represent a deliberate choice to act virtuously rather than being motivated by external pressures. In this context, engaging more than usual in activities like recycling or saving energy may be seen as a conscious decision to contribute to something meaningful, reflecting a sense of authenticity and autonomous decision-making. Furthermore, considering the need for competence, engaging in PEBs daily can be a way to express one's best capacities (Huta & Ryan, 2010; Lerner et al., 2015), and this sense of mastery can in turn promote ML (Martela et al., 2024).

Importantly, although adolescents often exhibit a decline in environmental engagement (e.g., Zhang et al., 2023) these results suggest that direct experiences, or personal reflection on such experiences (Bandura, 2001), can play a significant role in promoting dimensions of well-being connected to morality (Ryan & Deci, 2001; Wray-Lake et al., 2019). These within-person results, which reflect state-like fluctuations in behaviors and experiences, are separated from the trait-like average components (Hamaker et al., 2018). This suggests that what is linked to increases in well-being is the positive deviation from an individual's typical level of PEB. In other words, even if an individual's frequency of PEBs is lower than another's, it is the deviation from their own average, engaging more in meaningful actions on a given day, that is associated with a subsequent increase in ML.

On the other hand, contrary to our expectations and previous studies, PEB did not predict higher levels of CO. This result may align with Carrero et al. (2020), suggesting that this dimension of EWB may be influenced by the degree to which one's actions are perceived and accepted by others. While some PEBs can foster solidarity and belonging, others, especially those performed in public or that deviate from social norms, may create tension or conflicts. In our study, some PEB items involved visible actions (e.g., recycling) or behaviors requiring direct engagement with others (e.g., asking people to behave sustainably). During adolescence, when peer approval and social status are major concerns, engaging in behaviors perceived as unconventional may challenge, rather than strengthen, feelings of connectedness to others (Thomaes et al., 2023). These results suggest that although higher engagement in PEBs may strengthen one's sense of belonging and feeling of being valued by others (Mac Donald & Staats, 2022), for adolescents, whether PEB fulfills the need for positive social bonds (Kemper et al., 2024), may also depend on other contextual factors. Future studies should examine how peer approval and social expectations moderate the relationship between PEB and this dimension of EWB.

Finally, the residuals of PEB and ML were positively correlated, as were the residuals of PEB and CO (Model 1 and 2, respectively). This suggests positive same-day associations between PEB and both well-being dimensions, possibly indicating a co-occurrence that future studies should further investigate, as it may partly reflect the influence of unmeasured or situational factors.

Regarding the reverse spillover from ML/CO to PEB, we did not observe a significant effect. This result suggests that experiencing higher levels of well-being than one's usual may not necessarily lead to increased PEB engagement. One potential explanation is that the fulfillment of basic needs may already have been achieved, reducing the need for further behavioral engagement. Alternatively, individuals may be driven to engage in PEB not solely by self-transcendent or moral reasons, but also by material or hedonic incentives, such as financial rewards or personal pleasure (Steg et al., 2014). For example, individuals may be more inclined to conserve energy or water at home due to the potential for financial savings, rather than out of environmental concern. Additionally, individuals may be driven by the desire to gain social status, particularly through public behaviors (Steg, 2016), including encouraging others to adopt environmentally friendly practices. This may be plausible in our study, as adolescents strongly seek social approval and integration (Thomaes et al., 2023). However, being exploratory, this result should be further investigated in future studies, as previous literature mostly considered well-being as an outcome rather than a predictor of PEB (e.g., Carrero et al., 2020; Prati et al., 2017; Prinzing, 2024). Results also revealed positive carry-over effects for PEB, indicating that when adolescents engaged in more pro-environmental actions than usual on a given day, they were more likely to maintain these behaviors the following day, in line with previous literature (Caldaroni et al., 2025; Nilsson et al., 2017). Similarly, the increased levels of EWB tended to persist on subsequent days, consistent with findings from recent studies (Caldaroni et al., 2025; Gregori et al., 2024). In line with SCT (Bandura, 2001), we can speculate that engaging in self-reflection over four weeks may have heightened participants' awareness of their involvement in environmental action and its personal significance, which in turn could have sustained their engagement in PEBs and enhanced their experiences of eudaimonia.

At the between-person level, we observed small to moderate between-person variability in the spillover effect from PEB to ML and in the carryover effects of the three variables. Specifically, for some participants, the influence of PEB on ML was more pronounced. Additionally, we observed small-to-moderate variability in both carryover effects. To further explore whether such heterogeneity could depend on individual differences in S-TRV (Steg, 2016; Venhoeven et al., 2013), we examined the moderating role of S-TRV as a stable, trait-like variable in shaping the strength of the spillover and carryover effects (Model 2). However, we did not find any significant cross-level interaction effect, indicating that participants' carryover and, importantly, spillover effects from PEB to ML were not dependent on their level of S-TRV. This finding is relevant for this age group as it shows that PEBs can enhance daily sense of life significance for individuals with diverse levels of S-TRV. Additionally, it highlights that individual differences in S-TRV do not appear to influence the persistence of engagement in these behaviors in a short-term frame. Given that our sample size is underpowered to detect small cross-level effects, these null findings should be interpreted with caution. Future studies should replicate these exploratory results and investigate the role of different between-person factors that may help explain inter-individual differences in PEB engagement and well-being in daily life. Beyond values, personality characteristics such as traits, self-identity, and self-regulation abilities could contribute to these differences (Nielsen & Hofmann, 2021; Soutter & Mõttus, 2021; Steg, 2016; Thomaes et al., 2023). For example, Agreeableness and Conscientiousness (Markowitz et al., 2012), as well as stronger environmental self-identity and personal norms (Zeiske et al., 2021), have been linked to higher pro-environmental engagement. Adolescents with higher perceived self-control may also be more effective at translating intentions into behavior (de Leeuw et al., 2015). In turn, because acting in ways that align with one's tendencies, deeply held principles, and identity - as well as feeling effective in pursuing one's goals-is central to well-being (Ryan & Deci, 2001), these person-level factors may also contribute to between-person variability in the extent to which adolescents derive eudaimonic experiences from their daily PEBs. Identifying which characteristics amplify or weaken these dynamics represents an important direction for future research and intervention.

In contrast, S-TRV were associated with higher mean levels of PEB over the four weeks, meaning that individuals with higher S-TRV engaged more in PEB, in line with existing literature (e.g., Steg, 2016). Similarly, S-TRV were associated with higher average levels of ML and CO, that is, participants who prioritize more than others the collective welfare, also reported higher experiences of eudaimonia over the four weeks.

These findings contribute to the environmental literature on adolescence by highlighting the role of PEBs as pathways to relevant well-being experiences in a group that is highly vulnerable to the mental health impacts of environmental challenges (Pereira & Freire, 2021). The study's within-person approach is crucial for understanding these phenomena as dynamic psychological processes unfolding within individuals, rather than as stable interindividual characteristics (Kuper et al., 2021), laying the groundwork for potential causal inferences (Rohrer & Murayama, 2023).

5. Limitations

Despite the strengths of the present study, several limitations should be acknowledged in this study. Firstly, it only considers daily time-lagged relationships, which may not fully capture the dynamics between PEB and EWB over shorter or longer time frames. Future research should explore different time lags (e.g., hours or weeks) by adopting alternative ESM designs, such as Ecological Momentary Assessments (Shiffman et al., 2008), to gain a deeper understanding of these associations and examine the robustness of the findings. EMA may be better suited to capture the immediate psychological benefits of PEBs, which may be especially relevant given adolescents' sensitivity to short-term rewards (Thomaes et al., 2023). Accordingly, future research could consider shorter assessment intervals (e.g., assessing momentary changes in PEBs and well-being twice per day, at school and at home), allowing sufficient time and opportunities for adolescents to enact these behaviors, while capturing moment-to-moment effects. In this sense, daily diary and ecological momentary assessment approaches may be complementary in studying the benefits of PEBs in adolescents' daily lives, with daily diaries capturing short-term effects across days and ecological momentary assessments offering insight into the immediate benefits of PEBs for adolescents' well-being.

Moreover, relying on self-report measures may have contributed to an overestimation of the associations due to the same-informant method, underscoring the value of complementary observational or objective data (e.g., Xia & Liu, 2021) to reduce common method bias. Secondly, regarding construct measurement, this study included a limited number of PEB and EWB items due to practical constraints. As part of a larger intensive longitudinal study, survey length was optimized to maintain data quality. Future studies should focus on other relevant, high-impact PEBs (Nielsen et al., 2024) such as choosing plant-based meals (Wynes & Nicholas, 2017) or reducing food waste (Schanes et al., 2018), which adolescents can engage in their daily lives. Additionally, although single-item measures may be appropriate in experience sampling research when assessing narrow construct domains and may be perceived as easier by participants (Gabriel et al., 2019), we acknowledge the limitations of this approach. As multiple items typically enhance measurement reliability and allow to better encompass the relevant facets of a construct compared to single-item measures, future studies should employ multiple-item measures and conduct validation studies to obtain stronger assessments of within-person fluctuations. Moreover, beyond ML and CO, other relevant dimensions of eudaimonic well-being, both individual and interpersonal (Martela & Sheldon, 2019) – should be explored, as they may influence and be shaped by adolescents' pro-environmental engagement. According to Ryff and Singer's (2008) operationalization of EWB as psychological well-being, PEBs can foster self-acceptance, that is, developing a positive

view of oneself and one's past through actions perceived as meaningful and morally valuable (Venhoeven et al., 2017). PEBs may also sustain personal growth, reflecting the actualization and expansion of one's potential as adolescents mobilize their personal resources to address environmental challenges (Gomez-Baya et al., 2020). Additionally, PEBs may contribute to environmental mastery, namely shaping one's context to pursue desired goals (Carrero et al., 2020). A further relevant component is social well-being (Keyes, 1998), which refers to the perception of contributing to and being integrated within society; since PEBs are civic actions, they may support adolescents' sense of societal contribution (Wray-Lake et al., 2016).

Finally, in line with Huta and Ryan's (2010) view of eudaimonia as developing the best in oneself, experiencing one's actions as aligned with deeply held values - particularly moral ones - may elicit profound well-being experiences (Bartolo, Palermiti, et al., 2023). Future studies could explore how these different facets of EWB unfold in adolescents' daily lives, identifying which aspects are mostly affected by PEB and which, in turn, help sustain such behaviors over time.

Thirdly, we acknowledge that we did not conduct a formal power analysis for the present study. For power considerations, we followed the recommendations proposed by Maas and Hox (2005), who recommend including at least 50 participants for multilevel analyses involving nested data structures. Moreover, our final sample size was shaped by financial constraints associated with conducting the study.

Fourthly, regarding covariates, we explored gender and self-transcendence values as potential sources of between-person variability in these temporal dynamics, while age was not included due to limited variability in the sample. However, given the limited power to examine time-invariant covariates, we expect that future studies with larger samples will be better positioned to examine inter-individual differences, particularly the moderating role of self-transcendence values and personality traits such as Conscientiousness and Agreeableness (Markowitz et al., 2012). Moreover, the gender imbalance in our sample, characterized by a higher proportion of males, may have influenced the observed associations and thus, the generalizability of the findings across genders may be reduced. As females generally report greater engagement in PEBs (e.g., Rainisio et al., 2022), we do not exclude that future studies with more balanced samples may find significant effects on the relationship between PEB and EWB. Notably, there might also be time-varying covariates that could be considered in future research. For instance, because stress may negatively influence PEB (e.g., Kaida & Kaida, 2019), days on which adolescents experience more stressful events might also be days on which both their PEB and their well-being are lower than usual. Conversely, on days characterized by situational factors that support pro-environmental action - such as perceived social support - PEB may be higher (Gregson & Piazza, 2025). Controlling for these potential time-varying covariates in future research could help tease apart the unique effect of PEB on EWB. Lastly, the observational nature of the intensive longitudinal design used prevented drawing strong causal conclusions due to the potential influence of uncontrolled factors (Rohrer & Murayama, 2023). To overcome such a limitation, combining within-person data with experimental methods could be a valid approach (Caldaroni et al., 2025; Hamaker & Wichers, 2017; Schmiedek & Neubauer, 2020).

6. Conclusion

This study highlights the role of daily PEBs in promoting profound experiences of well-being such as greater meaning in life in adolescents' everyday lives. Importantly, these benefits are not solely driven by inherent tendencies to care for others or the environment, namely personal values, but can also emerge from everyday behaviors that can promote personal agency (Sawitri et al., 2015).

From a developmental and intervention standpoint, promoting daily PEBs may be especially valuable during adolescence, a period marked by a decrease in such behaviors (Krettenauer, 2017), increased vulnerability to the negative effects of environmental issues on mental health (Pereira & Freire, 2021), and a general decline in well-being (López-Pérez & Zuffianò, 2021). Encouraging reflection on their daily engagement in these behaviors can strengthen sustainable habits and promote long-term well-being (Bartolo et al., 2023; Ojala, 2022), supporting adolescents in navigating environmental issues (Ojala, 2005) as well as their developmental challenges (Arnett, 2007; Lerner & Galambos, 1998).

CRediT authorship contribution statement

Silvia Caldaroni: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Maria Gerbino:** Writing – review & editing, Supervision, Investigation, Conceptualization. **Florian Schmiedek:** Writing – review & editing, Validation, Methodology. **Andreas Neubauer:** Writing – review & editing, Validation, Methodology. **Elisabetta Beolchini:** Writing – review & editing, Investigation, Data curation. **Alessia Teresa Virzì:** Writing – review & editing, Investigation, Data curation. **David Lundie:** Writing – review & editing, Project administration, Investigation, Funding acquisition. **Ólafur Páll Jónsson:** Investigation, Funding acquisition. **Bernadette Paula Luengo Kanacri:** Investigation, Funding acquisition. **Diana Camps:** Writing – review & editing, Investigation. **Kristian Guttesen:** Writing – review & editing, Investigation. **Virginia Isabel Barrero Toncel:** Writing – review & editing, Investigation, Data curation. **Fulvio Gregori:** Writing – review & editing, Investigation, Data curation. **Valentina Paz Quilodrán Fuentes:** Writing – review & editing, Investigation, Data curation. **Concetta Pastorelli:** Supervision, Investigation, Conceptualization. **Antonio Zuffianò:** Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Data statement

The analyses, scripts, outputs and datasets used in this article can be accessed at the following OSF link: https://osf.io/bafmq/?view_only=17165c0b9bbd4461b5138e289836cf78.

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Declarations of interest

None.

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