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WASHINGTON UNIVERSITY IN ST LOUIS

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The Role of Affect and Exercise Goals in Physical Activity Engagement in Younger and
Older Adults

by

Marta Stojanovic

A dissertation presented to
The Graduate School
of Washington University in
partial fulfillment of the
requirements for the
degree of Doctor of Philosophy

August 2022
St. Louis, Missouri

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ABSTRACT OF THE DISSERTATION

The role of affect and exercise goals in physical activity engagement in younger and older adults

by

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Doctor of Philosophy in Psychological and Brain Sciences

Washington University in St. Louis, 2022

Professor Denise Head, Chair

Despite potential benefits of physical activity engagement for older adults, individuals over the age of 65 were more likely to report physical inactivity compared to younger and middle-aged adults. It is extremely important to understand factors influencing regular engagement in physical activity in older adults, particularly the role of affective response and exercise goals which have been greatly overlooked. Mixed findings have been reported in terms of age differences in affective response to daily physical activity while exercise goals in younger and older adults have not been thoroughly compared. Hence, the goal of this project was to determine age differences in affective response to daily physical activity and exercise goals and whether these differences are associated with overall physical activity levels. Younger ($n=47$) and older adults ($n=47$) completed one week of experience sampling during which they responded to daily prompts about their affect and physical activity. Overall physical activity levels were estimated via actigraphy. Across age groups ($p=0.138$), daily physical activity was found to be associated with greater high arousal positive affect relative to other activities ($p<0.001$). Generally, social context was not a significant moderator of affect after daily physical activity ($p < 0.082$), however, there was some evidence to suggest that being outdoors ($p<0.033$) and enjoying daily physical activity ($p=0.001$) was associated with greater high arousal positive affect in younger

adults. In terms of exercise goals, older adults reported greater orientation towards instrumental relative to hedonic exercise goals compared to younger adults ($p=0.027$). Neither affective responses ($p=0.488$) nor exercise goals ($p=0.912$) were associated with overall physical activity levels. These results suggest that engagement in daily physical activity was associated with greater high arousal positive affect in younger and older adults. In addition, these affective responses and exercise goals may have a limited role in regular, sustained physical activity engagement.

Chapter 1: Introduction

Older adults are at higher risk for developing cardiovascular diseases (Mozzaffarian et al., 2016), one of the leading causes of death among older adults (Myers, 2003; Mozzaffarian et al., 2016), as well as cognitive and brain decline (e.g., Raz, 2000; Salthouse, 2010). In addition, epidemiological studies reveal that the prevalence of depressive symptoms among community-dwelling older adults, while lower than the prevalence of younger adults (e.g., Henderson et al., 1998; Jorm, 2000), still ranges from approximately 8% to 16% (Blazer, 2003). Prevalence of anxiety symptoms is approximately 15% (Mehta et al., 2003). Furthermore, sedentary behavior has been associated with increased incidence of cardiovascular diseases, obesity, and mortality (Thorp et al., 2011). On the other hand, engaging in regular physical exercise was found to reduce the risk of developing cardiovascular disease. In addition, exercise has also been associated with enhanced affect and alleviation of depressive and anxiety symptoms (Blumenthal et al., 1989). Finally, there is some evidence to suggest that exercise interventions are associated with improved cognitive performance and increases in brain volume and connectivity (e.g., Colcombe et al., 2006; Kramer et al., 2006). Importantly, in spite of the multiple potential benefits of exercising for older adults, people over the age of 65 (31.9%) were more likely to report physical inactivity in 2019 compared to younger (19.3%) and middle-aged (26.2%) adults (CDC, 2019). Among those reporting engagement in some physical activity, approximately one third of older adults over the age of 65 (Keadle et al, 2016), compared to 38% of younger adults (Valle et al., 2015), engage in sustained, regular physical activity, defined as exercising five times a week for at least 30 minutes. Furthermore, approximately 50% of people of all ages drop out of an exercise program within the first few months (Dishman & Buckworth, 1997; Linke et

al., 2011). Hence, it is crucial to understand the barriers to engaging in physical activity and planned exercise regimens, particularly among older adults.

It is important to make a distinction between *physical activity* and *exercise*, even though studies in the literature sometimes use these terms interchangeably (e.g., Scholz, Sniehotta, Burkert, & Schwarzer, 2007; Conn, Tripp-Reimer, & Maas, 2003). Physical activity is a broader term that refers to a bodily movement that requires energy expenditure, while exercising includes planned engagement in a structured program with the goal of improving fitness (Caspersen, Powell, & Christenson, 1985). There are potentially many factors contributing to sustained engagement in exercise/physical activity, such as physical health, demographic characteristics, neighborhood characteristics, attitudes, and self-efficacy, to list a few. Across the lifespan, greater reported health, intention to exercise, self-efficacy, male sex, and prior physical activity were found to be associated with greater engagement in physical activity (e.g., review Bauman et al., 2012). In addition, a relatively recent review of reviews by Choi and colleagues (2017) suggested that self-efficacy and neighborhood accessibility are most consistently shown to be associated with physical activity. Hence, different models have been proposed to account for the number of factors potentially contributing to sustained, regular engagement in exercise and physical activity.

The majority of the models of physical activity/exercise adherence have focused on attitudes and beliefs about exercising (Ajzen, 1991), environmental barriers (Barnett et al., 2017), or other cognitive determinants (e.g., self-efficacy; McAuley et al., 2000). Models that require a more planned approach are better suited for explaining exercise engagement (Ajzen, 1991), while models that rely more on attitudes and beliefs (Rosenstock et al., 1988) might be applied to both exercise and physical activity adherence. More recently, multicomponent frameworks have been

proposed to account for exercise and physical activity behavior (e.g., Lachman, Lipsitz, Lubben, Castaneda-Sceppa, & Jette, 2018). This multicomponent approach proposed by Lachman and colleagues (2018) lists personal (e.g., age, personality) and environmental (e.g., neighborhood, norms) factors that influence behavior change mechanisms, such as self-efficacy, social support, beliefs about the behavior, outcome expectations, and self-regulation. These behavior change mechanisms in turn influence physical activity behavior, which then has a reinforcing impact on the mechanisms.

However, the role of short-term consequences, as part of the behavior change mechanisms in regular physical activity and exercise engagement, has been greatly overlooked, especially in the aging literature. More recently, researchers have proposed that affective responses to exercise can play a significant role in future physical activity behavior (Williams, 2008; Bryan et al., 2013). In addition, the aforementioned multicomponent model of physical activity behavior suggests that positive affective response could lead to greater enjoyment and goal attainment in the physical activity behavior (Lachman et al., 2018). Hence, in addition to experiencing positive affect *during* and *after* exercising, it may also be important to have the goal of enjoying the exercise (Ryan et al., 1997; Dacey et al., 2008). There is a gap in the literature in terms of examining the role of affective responses to bouts of exercise/physical activity in the overall physical activity levels in both younger and older adults. Furthermore, there is a dearth of studies directly examining age differences in exercise goals and whether they predict overall physical activity levels in both younger and older adults.

The primary goal of this dissertation is to gain insight into age differences in potential factors that contribute to physical activity engagement. More specifically, this dissertation will focus on understanding the affective responses to bouts of physical activity in daily life and associations

of these affective responses with overall physical activity levels. Another goal is to examine how exercise goals, in isolation and interacting with affective responses, are associated with overall physical activity levels in younger and older adults.

1.1 The role of affect in exercise/physical activity adherence

The most prominent models of exercise/physical activity adherence typically include cognitive determinants (e.g., Ajzen, 1991; Rosenstock et al., 1988) and have generally overlooked the role of short-term consequences, more specifically affective responses. It is not until more recently that researchers started to incorporate the hedonic theory (Bentham, 1789; 2007) into conceptualizations of exercise adherence. According to this theory, people seek behaviors that prolong pleasure and avoid pain (e.g., Higgins, 1997; Thorndike, 1911). Applying the principles of hedonic theory to exercise adherence, a causal chain has been suggested in models of exercise/physical activity behavior such that a bout of exercise leads to positive affective responses, which in turn leads to adherence (Posner et al., 2005; Williams, 2008; Bryan et al., 2011). Studies indicated support for the causal chain by showing that positive affective response during and after exercise was associated with greater physical activity engagement at 3-month, 6-month, and 12-month follow-ups among younger adults (Kwan & Bryan, 2010; Williams et al., 2008; Williams et al., 2012; but see Bryan et al., 2013). Furthermore, a qualitative review concluded that positive affect *during* moderate-intensity exercise, more so than the *post*-exercise affect in response to moderate-intensity exercise, was associated with greater engagement in physical activity in the future (Rhodes & Kates, 2015). Therefore, it appears that the change in affect, perhaps particularly during exercise, has the potential to influence future behavior in a population of younger adults. An important question to consider is whether older adults receive less affective benefit from an acute bout of exercise and daily physical activity, more broadly. In

addition, it is crucial to examine whether these potential age differences in affective response explain why older adults are usually found to have lower overall physical activity levels.

More recently, researchers have proposed that the effects of exercise are better estimated by sampling from the affective circumplex (Russell, 1980; Ekkekakis, 2003). The affective circumplex, consisting of two underlying dimensions of arousal and valence, can be particularly useful in mapping out the effects of exercise and physical activity. The affective circumplex can be separated into four quadrants based on the valence and arousal dimensions, including high arousal positive (HAP) affect, low arousal positive (LAP) affect, high arousal negative (HAN) affect, and low arousal negative (LAN) affect. In addition, Ekkekakis and colleagues proposed a three-phase model to account for affect changes observed during and after an acute bout of exercising (Ekkekakis et al., 2008; Ekkekakis et al., 2000; Ekkekakis, 2003). This three-phase model proposes that: 1) cognitive factors (e.g., goals, self-efficacy, attributions, appraisals, and willingness to endure strenuous activity) lead to positive valence at the beginning of exercising; 2) once the person reaches ventilatory threshold, negative affect is produced since physiological and metabolic strain responses become the dominant input and overcome cognitive factors; 3) termination of exercising produces a rapid shift to positive affect due to release of endogenous opioids and a shift back to cognitive factors. Initial studies conducted among younger adults suggested that the affective changes during and after exercising corresponded to the proposed changes of the model, along with the physiological cues (Ekkekakis et al., 2008). Older adults were found to have a lower ventilatory threshold at which physiological cues produce negative affect (Cunningham et al., 1987). Thus, older adults could experience an earlier increase in metabolic strain and a slower return to baseline from a higher peak, resulting in a prolonged

period of negative affect during exercising and less increase in high arousal positive affect after acute exercise, as well as daily physical activity.

1.2 Daily physical activity and affect in younger and older adults

While examining the association between acute exercise and affective response in laboratory settings is essential for understanding the mechanism of the effect of exercise/physical activity on affect, it is also important to investigate whether exercising and/or physical activity influences affect in naturalistic settings. The Ecological Momentary Assessment (EMA) method is particularly conducive for examining whether daily physical activity impacts affect or if the relationship could be bidirectional (Dunton, 2017). Furthermore, the EMA design facilitates examination of within-person relationships (Kanning et al., 2013). For example, between-person effects can indicate the effect of person-level differences (e.g., age, gender, personality) on affective response to daily physical activity while within-person effects can reveal which variables (e.g., stress, sleep, social context) co-occur and influence variability in affective response to daily physical activity day to day. This method also provides the ability to examine contextual information that might moderate these effects, such as social and physical context; hence, it has become increasingly more popular in the physical activity/exercise literature. A review of studies using EMA design found that bouts of daily physical activity were associated with subsequent increased positive affect in healthy individuals across the age range, while the relationship with negative affect was mixed (Liao et al., 2015). The studies done exclusively with middle-aged and older adults have yielded equivocal results (Kanning & Slicht, 2010; Dunton et al., 2009). These studies have either used a different approach to mood assessment (Kanning & Slicht, 2010) or were characterized by a small sample size (Dunton et al., 2009).

Furthermore, a study by Liao et al. (2017), done primarily in young and middle-age adults (mean age 39.8), found that feeling more energetic during daily physical activity was associated with greater physical activity engagement at a 6-month and 12-month follow-up, while feeling less negative during the bout of activity was positively associated with physical activity levels at a 12-month follow-up. However, this study had a small sample size of participants and small number of prompts where physical activity was endorsed, hence, these findings should be interpreted with caution. All of the aforementioned studies relied on assessing emotion during or immediately after physical activity rather than delayed recalling of how people felt.

There is an important gap in terms of directly comparing the relationship of daily physical activity with affect between younger and older adults, which is critical for determining whether age differences in affective response may contribute to lower overall physical activity levels. Research does indicate that older adults experience less variability in their emotional states (e.g., Rocke et al., 2009) and they are both less likely to experience and less likely to prefer high arousal positive affect (Scheibe et al., 2013). On the other hand, acute aerobic exercise was found to lead to an increase in high arousal positive affect in adults (e.g., Ekkekakis et al., 2000; Hogan et al., 2013; meta-analysis Reed & Ones, 2006). There is a gap in the literature in directly comparing age groups in terms of positive and negative emotional states during and after daily physical activity that vary across the dimension of arousal.

There are several contextual factors shown to influence the affective response to bouts of daily physical activity, with one of them being social context (Dunton et al., 2015). Exercising in a group versus alone was found to be associated with greater positive affect after acute exercise and daily physical activity in adults (McAuley et al., 2000; Dunton et al., 2015). Furthermore, social support seems to be particularly relevant for regular physical activity in older adults

(Resnick et al., 2002). Work based on socioemotional selectivity theory provided evidence that older adults place greater importance on socioemotional goals and quality of relationships that can help them regulate their emotions compared to younger adults (Carstensen, 1992; Carstensen et al., 2003; Lockenhoff & Carstensen, 2004). More specifically, older adults prefer to spend time with closer social partners, hence, older adults might show more positive affect after engaging in daily physical activity with others, especially close social partners, relative to younger adults. There is a need for examination of potential age differences in affective responses to bouts of daily physical activity and how they are influenced by social context.

1.3 Exercise Goals

While motivation and goal-setting have been highlighted as important contributors to physical activity behavior (e.g., Rosenstock et al., 1988; Gollwitzer, 1999), there is a dearth of studies examining how exercise goals influence overall physical activity levels across age groups. Goals related to enjoyment, appearance/weight, fitness/health, and social engagement are among goals people have endorsed for exercising (Ingledeu & Markland, 2008). Important to note is that people can endorse the different types of exercise goals at the same time to a varying extent. Goals related to fitness, health and appearance have been more thoroughly examined in the literature compared to the goal of enjoyment. For example, in a study of middle-aged adults and their exercise goals, health and fitness goals were associated with greater participation in physical activity. This was not the case for appearance, weight, or social engagement goals and goals related to enjoyment or immediate gratification were not examined (Ingledeu & Markland, 2008). Even though both younger and older adults most commonly endorse health/fitness goals relative to other exercise goals, when examined, the goal of enjoyment was found to be most predictive of physical activity levels for younger adults (Ryan et al., 1997; Ednie & Stibor, 2017)

and older adults (Dacey et al., 2008). Furthermore, exercise programs that increase enjoyment of exercise were found to lead to greater long-term exercise adherence (e.g., Jekauc, 2015). These results highlight the possibility that greater endorsement of the goal of enjoyment can potentially lead to greater participation in regular, sustained exercise/physical activity. A study by Quindry et al. (2011) examined exercise goals across the adult lifespan in active individuals. They found that fitness goals were consistently important across age groups. Health goals were rated higher for older adults while competition and social recognition goals were rated higher for young adults. Interestingly, the goal of enjoyment and affiliation were endorsed to a similar extent across all age groups.

It has been commonly done in different areas of psychology to classify goals into hedonic and instrumental (e.g., Dijkstra et al., 2015; Tamir, 2009). Hedonic goals serve the purpose of an immediate benefit and gratification, while instrumental goals serve the purpose of increasing one's resources and improving the situation in the longer run (Dijkstra et al., 2015). While this classification has not been applied to physical activity/exercise literature, it can be proposed that exercise goals can also be classified into hedonic (e.g., feeling better, enjoying exercise) and instrumental (e.g., being healthier, looking more fit) goals. To further highlight the distinction, the hedonic goals could be conceptualized as mostly short-term goals while instrumental goals would fall more frequently into the category of long-term goals. However, to my knowledge, no study directly compared the endorsement of exercise goals and how they relate to overall physical activity levels in both younger and older adults.

Socioemotional selectivity theory posits that goals related to emotional meaning are prioritized over goals that increase long-term benefits with increasing age (Carstensen et al., 1999), hence, one idea might be that older adults will show greater orientation towards hedonic goals than

younger adults. However, it is also possible that older adults might show greater orientation towards instrumental goals than younger adults. Health goals, which can be thought of as the primary component of instrumental goals, were endorsed to a greater extent in older adults than younger adults (Quindry et al., 2011). This finding might result from greater saliency of health concerns and health management strategies for older adults. Older adults were more than twice as likely as younger adults (40% of older adults compared to 16% of younger adults) to receive a recommendation to exercise from their physician (Barnes & Schoenborn, 2012). Hence, it is possible that older adults receive more messages from physicians and other people that physical activity is important for their health. In addition, older adults tend to experience more rapid decline in their physical health (e.g., reduced mobility), which could lead to increased awareness towards physical functioning and greater emphasis on strategies to improve their health. These factors might influence older adults to place greater importance on instrumental goals relative to hedonic goals than younger adults in this particular context. Furthermore, age differences in exercise goals orientation might explain potentially lower overall physical activity levels in older adults. As mentioned above, the goal of enjoyment was especially predictive of engagement in physical activity (Ednie & Stibor, 2017; Dacey et al., 2008), hence, greater orientation towards hedonic goals might promote physical activity. Potential greater endorsement of instrumental goals relative to hedonic goals by older adults compared to younger adults might explain the lower overall physical activity levels in this population.

There is also a relative dearth of studies examining how exercise goals interact with the affective responses to daily physical activity and consequently predict overall physical activity levels. As previously mentioned, not all studies have found a significant relationship between affective responses and physical activity/exercise adherence, suggesting that this effect might be

moderated by other factors. For example, a meta-analysis by Rhodes and Kates (2015) found that affective responses contributed very little to intention to exercise in the future or self-efficacy, but were significantly associated with affective judgment, i.e., the prediction of the affective response during and after exercising in the future. However, no study has systematically examined exercise goals as a potential moderator. The extent to which a person is oriented towards and emphasizes hedonic versus instrumental goals might moderate the relationship between affective responses and overall physical activity levels. The positive affective response might be more strongly predictive of overall physical activity levels when greater value is placed on hedonic goals versus instrumental goals. If people have the goal of enjoying the exercise, greater positive affect associated with daily physical activity might be more impactful to overall physical activity levels compared to placing greater importance on the goals of being fit and healthy. Hence, exercise goals orientation might not only play a direct role in overall physical activity levels but also indirectly have an effect on the association between affective response to daily physical activity and overall physical activity levels.

1.4 Summary and Specific Aims

Almost no studies have directly compared how daily physical activity influences affect in younger and older adults, which would serve the goal of understanding whether daily physical activity impacts affect differentially in younger and older adults in everyday life. In addition, there is a relative dearth of studies investigating how these affective responses contribute to overall physical activity levels in both younger and older adults. Due to the nature of experience sampling, it is unlikely that a sufficient number of prompts will occur during moderate intensity daily physical activity (Kanning et al., 2013), hence, the study will focus on affect after a bout of daily physical activity. Therefore, I hypothesize that older adults will experience smaller increase

in high arousal positive affect after bouts of daily physical activity compared to younger adults. I also hypothesize that engaging in daily physical activity with others will increase positive affect more than being alone, particularly for older adults. Finally, I hypothesize that smaller increase in high arousal positive affect after daily physical activity will mediate the effect of age on overall physical activity levels. A secondary set of analyses will explore how daily physical activity impacts high arousal negative, low arousal negative, and low arousal positive affect in younger and older adults.

Additionally, another important factor to consider are exercise goals, which are found to be associated with physical activity engagement (Markland & Ingledew, 2008). To my knowledge, no study has directly compared age differences in exercise goals and whether they subsequently predict overall physical activity levels. I hypothesize that older adults will endorse instrumental goals to a greater extent than hedonic goals compared to younger adults. In addition, I hypothesize that greater endorsement of instrumental goals will mediate the effect of age on overall physical activity levels. To my knowledge, there is no prior work that examined the exercise goals as a moderator of the relationship between affective responses to daily physical activity and overall physical activity levels. The impact of positive affective responses on overall physical activity levels might be more important when people endorse that their exercise goals are related to feeling immediately better. Hence, I hypothesize that, collapsed across age, a stronger association between high arousal positive affect and overall physical activity levels will be present with greater endorsement of hedonic goals compared to instrumental goals. A planned exploratory analysis examined whether this association differs in younger versus older adults.

Chapter 2: Method

2.1 Participants

51 younger adults (age mean: 20, SD: 1, range: 18-23) were recruited from the Washington University student community and 49 older adults (age mean: 67, SD: 6, range: 59-88) were recruited from the St. Louis and Columbia, Missouri, community. Sedentary individuals, as defined by engaging less than once a week in moderate intensity physical activity, individuals without a smart phone, and individuals with cognitive decline (as estimated via a brief cognitive screen), were excluded from the study (except for one sedentary individual through experimenter error)¹. Four participants (two young adults and two older adults) had a history of depression diagnosis and two participants (young adults) had a history of ADHD diagnosis. Two participants (one younger adult and one older adult) were taking antidepressants at the time of the experiment.²

Software malfunction prevented download of actigraphy for two individuals (two young adults) and download of EMA data for one individual (one older adult), hence, they were excluded from the analysis because they were missing either one of those datasets. Two participants (young adults) were excluded because they did not meet criteria for valid actigraphy data (see below section 2.6.2). One individual (older adult) responded to all of the positive emotion terms with the highest rating (extremely) and all of the negative emotion terms with the lowest rating (not at all) in all of their completed prompts. In addition, this participant also gave the highest rating (very true for me) on all of the items of the EMI-2, indicating the greatest extent of endorsement for all exercise goals. Even though their response speed did not seem unusually fast, due to lack

¹ None of the main analyses were different when the sedentary individual was excluded.

² None of the main analyses were different when the individuals with psychiatric diagnoses were excluded.

of variation in the responses, this participant was excluded from the analyses. The final sample included 94 participants (47 younger adults and 47 older adults). The original power analyses estimated that the sample size of 132 individuals provides at least 80% power to detect effects in the moderate range. Furthermore, a sample size of at least 100 individuals was deemed necessary to detect between-group effects in the EMA design (e.g., Silva et al., 2014; Matthieu et al., 2012).³

Both younger and older adult groups had 38 females and 9 males. In younger adult group, the racial distribution was: 14 Asian, 4 Black, 23 White (8 Hispanic), and 3 individuals endorsed more than one race. Three younger adults chose not to report their race. In older adult group, the racial distribution was: 1 Asian, 6 Black, and 39 White (1 Hispanic) individuals. One older adult was missing racial data. On average, older adults completed 17 years (SD: 2, range: 12-22) of education while younger adults completed 14 years (SD:1, range: 12-17) of education. Older adults endorsed average number of 0.33 medical diagnoses compared to 0.02 medical diagnoses for younger adults. See Table 1 for demographic characteristics and further information about the sample.

2.2 General Procedure

Ecological momentary assessment (EMA) was utilized, which involved a time-sampling method of surveying participants and providing momentary surveys of daily life. Participants completed 7 days of experience sampling. They chose their own time window of 15 hours during which they were surveyed. Prompts occurred five times a day randomly within five blocks of three hours (Burke et al., 2017). Prompts were delivered on a schedule generated via EMA software

³ The proposed sample size was not obtained due to difficulties with recruitment during the COVID-19 pandemic.

(Tay, 2005; ExpiWell) that can be utilized on both iOS and Androids. Participants received a notification through the ExpiWell app with a survey to be completed 5 minutes after this prompt. Participants received a reminder prompt if they had not completed the survey yet. They had 15 minutes to respond once they received the initial prompt.

In addition to answering the questions for their daily prompts, participants wore an actigraphy watch that is commonly used as an objective measure of physical activity (Lyden et al., 2014; Kanning et al., 2013). The actigraphy watch measured movement in three planes providing “counts” of acceleration signal which were later used to estimate Metabolic Equivalent (MET) and determine whether the person was sedentary or engaged in light, moderate, or vigorous physical activity. Participants were instructed to wear the watch during the duration of experience sampling of one week.

2.2.1 Training session and compliance monitoring.

Participants attended a training session before the start of their experience sampling. Examiners described to participants each of the questions that they were going to be receiving in their daily prompts. Participants needed to show understanding of each question and possible responses. They also went through the whole process of receiving the prompt and answering the survey with the examiner during the training. The examiner checked in with each participant after the first day of experience sampling and was available the rest of the week in case there was a need for troubleshooting.

The average EMA compliance was 81.75% which was above the recommended level of 80% (Cain et al., 2009). This means that on average participants completed 28 out of 35 prompts during the week of experience sampling. There were no significant differences in compliance between younger and older adults, although, as expected, older adults showed greater variability

in their compliance. While some older adults had low levels of compliance (e.g., 20%), all participants were retained in the analyses to maximize sample size.

2.3 EMA prompts

When receiving the initial prompt, participants were asked about their current affect to counteract any effects that asking about their engagement in daily physical activity first could have on their subsequent affect reporting. Affect was assessed by asking participants to indicate how much they currently experienced a list of feelings on a 5-point scale ranging from “very slightly/not at all” to “extremely” (see section 2.4 for description of the affective terms).

Then, participants were asked whether they engaged in any physical activity since the last assessment. If they responded “yes”, they were asked the following questions: (1) “How long ago did you engage in physical activity?” with the options of right before, and then 30 minute increments up to three hours; (2) “What was the duration of physical activity in minutes?” with the pull down menu of options ranging from 15 to 90 minutes; (3) “Were you engaged in that activity alone, with another person, or in a group?” with three response options; (4) If they indicated “with another person or in a group”, they were asked “What is your relationship with that person/group?” with the option of spouse/partner, family members, friends, coworkers, other types of acquaintances, and strangers. (5) “Was the physical activity done indoor or outdoor?” with the options of indoor, outdoor, and both indoor and outdoor. (6) “What was your peak level of enjoyment during the physical activity?” with the options ranging on a 7-point scale from enjoyed not at all to enjoyed extremely. (7) “What was your peak level of physical exertion during the physical activity?” with the options ranging from nothing at all to maximal exertion. (8) “What category best describes the physical activity?” with the options job-related,

housework/house maintenance, transportation, and leisure. (9) “Briefly describe what you did for the physical activity.”

If the participants responded “no” to the physical activity endorsement question, they were asked the same set of follow-up questions and in the same order as above, but they were asked to relate it to the other most recent activity that they had done prior to the prompt.

2.4 Measurement of Affect

Affective descriptions from the Affect Valuation Index (AVI; Tsai et al., 2006) in accordance with Barrett and Russell (1999), were used to assess affect during each prompt. This measure included affective terms across all four quadrants of the affective circumplex (Russell, 1980). For each affective term, the participants endorsed how much they currently felt this emotion on a 5-point scale ranging from “very slightly/not at all” to “extremely”. Based on the AVI, composites were created for high arousal positive (HAP), low arousal positive (LAP), high arousal negative (HAN), and low arousal negative (LAN) affect by averaging the assigned affective terms. After piloting several participants, three negative terms (two HAN and one LAN) from AVI did not show variation, hence, alternative terms from the affective circumplex were used in the study. High arousal positive affect included *enthusiastic*, *excited*, and *elated*. Low arousal positive affect included *calm*, *relaxed*, and *peaceful*. High arousal negative affect included *jittery* (substituted instead of fearful), *frustrated* (substituted instead of hostile), and *nervous*. Low arousal negative affect included *bored* (substituted instead of dull), *sleepy*, and *sluggish*.

Between person omega coefficients (internal consistency) were 0.97 for HAP, 0.98 for LAP, 0.92 for HAN, and 0.90 for LAN affect. Within person omega coefficients (internal consistency) were 0.77 for HAP, 0.76 for LAP, 0.54 for HAN, and 0.71 for LAN affect.

2.5 Exercise Goals

Participants completed a trait measure of their exercise goals – Exercise Motivation Inventory-2 (EMI-2) (Markland & Ingledew, 1997). EMI-2 was administered either before or after the experience sampling and the order was counterbalanced across participants. This self-report questionnaire included 14 subscales: stress management, revitalization, enjoyment, challenge, social recognition, affiliation, competition, health pressures, ill-health avoidance, positive health, weight management, appearance, strength and endurance, and nimbleness. The original subscales were shown to have good internal consistency and factor invariance across gender (Markland & Ingledew, 1997). A composite of hedonic goals was created by including stress management, revitalization, enjoyment subscales, and relevant items from the affiliation, challenge, social recognition, and competition subscales. Additional items were selected if they referred to the feeling of enjoyment, fun, or satisfaction (e.g., “I exercise to enjoy the social aspects of exercising,” “I exercise because I enjoy competing”). All of the items included in the hedonic goals composite indicated that exercising serves the purpose of an immediate benefit and gratification (Dijkstra et al., 2015). On the other hand, a composite of instrumental goals included health pressures, ill-health avoidance, positive health, weight management, strength and endurance, and nimbleness goals. All of the items included in the instrumental goals composite indicated that exercising serves the purpose of increasing one’s resources and improving the situation in the longer term (Dijkstra et al., 2015).

2.6 Accelerometry

2.6.1 Data acquisition

GT3X ActiGraph (Actigraph Corporation, Pensacola) accelerometer was used to objectively measure overall physical activity levels. At the beginning of the experiment, participants

received an adjustable belt and monitor inside a pouch. During the training session, they were instructed to wear the monitor on the right hip during all hours of the experience sampling week. In the ActiLife software, it was indicated that the watch was worn on the waist. Sampling frequency was set to 30Hz and binned into 60-second epochs resulting into timestamped accelerometry data.

2.6.2 Data processing

The Choi algorithm was used to validate wear time (Choi et al., 2011). This algorithm has been recommended for use with older adults (Migueles et al., 2018). According to the algorithm, non-wear time is defined as a period greater than 90 consecutive minutes of 0 counts per minute. The Cole-Kripke algorithm was used to determine sleep periods for each participant (Cole et al., 1992). Even though this algorithm has been primarily validated for wrist-worn actigraphy, it has been previously used to determine sleep in waist-worn actigraphy (Takeshima et al., 2016; Khou et al., 2018). The algorithm was further validated with EMA data to adjust the sleep period if necessary. All of the non-wear and sleep periods, that were determined by the aforementioned algorithms, were excluded from the participant's data since it was shown that including sleep periods can cause incorrect calculation of light physical activity and sedentary periods (Meredith-Jones et al., 2015). Then, only valid days (more than 10 hours of wear time) were included in the analysis of overall physical activity levels. Participants with less than two valid days of actigraphy data were excluded from the analyses. Two participants were excluded because they did not meet the criteria. This criteria has been chosen in order to exclude individuals with very low wear times while at the same time maximizing the sample size. Average wear time of actigraphy was 6.53 days (SD: 1.17, range: 2-8), meaning that on average participants wore the actigraphy watch for six and a half days out of the seven days of experience

sampling. There were no significant differences in wear time between younger and older adults, see Table 1.

The Sojourn method (Soj-3x) was applied to estimate metabolic equivalent (METs) (Lyden et al., 2014) It is a machine-learning algorithm that utilizes the 3-dimensional acceleration information to determine the METs. Then, each minute was classified into sedentary behavior (< 1.8 METs) or light (1.8-3.0 METs), moderate (3.0-6.0 METs), or vigorous (> 6.0 METs) physical activity. The overall physical activity levels estimate represented an average of time spent in moderate-vigorous physical activity (MVPA) relative to total wear time across valid wear days.

2.7 Questionnaires

Several questionnaires were administered to characterize the sample and examine potential covariates and moderators of the relationships between age, affective responses, and overall physical activity levels. The Affect Valuation Index (AVI) was used to measure actual and ideal affect. The items were described above (section 2.4). For actual affect, participants were asked to “rate how much you TYPICALLY feel each of the following items on average.” For ideal affect, participants were asked to “rate how much you IDEALLY feel each of the following items on average.” HAP, LAP, HAN, and LAN composites were calculated for both actual and ideal affect. The actual affect score was examined as a potential covariate in the models. The Beck Depression Inventory-II (BDI-II) was administered to assess depressive symptoms (Beck et al., 1961). The Beck Anxiety Inventory (BAI) was used to assess symptoms of anxiety (Beck et al., 1988). Both depressive and anxiety symptoms were examined as potential significant covariates in the models. Health composite represented accumulated count of current or past instances of:

stroke, diabetes, hypertension, cardiovascular disease, seizures, traumatic brain injury, Alzheimer's disease, Parkinson's disease, and Huntington's disease.

2.8 Statistical Analyses

All analyses were conducted using R statistical software v4.1.3 (RStudio Team, 2005). R package lmer was used for the HLM analyses (Pinheiro et al., 2018) and the R package mediation was used for the mediation analyses (Tingley et al., 2013). Daily physical activity was defined either via self-report (primary analyses) or via actigraphy (secondary analyses) and the same set of analyses were done for both self-reported and actigraphy-defined daily physical activity. Overall physical activity levels (MVPA) were always estimated with actigraphy. Results were similar between primary (self-reported daily physical activity) and secondary (actigraphy-defined daily physical activity) analyses unless otherwise noted in the Results section.

2.8.1 Covariates for affective responses to physical activity

Several covariates were determined a priori to examine a potential influence on affective response to daily physical activity. Each covariate was entered into the relevant model one by one to check for significant impact. Time of day (morning vs afternoon vs evening vs night), order in study, day of the week, and delay between the activity and the prompt were entered as potential prompt-level covariates. Education, gender, depressive symptoms (estimated via BDI-II), anxiety symptoms (estimated via BAI), and typical affect (estimated via AVI) were entered as potential person-level covariates.

2.8.2 Age differences in affective response to daily physical activity

An HLM model tested the hypothesis that older adults will experience smaller increase in high arousal positive affect after daily physical activity compared to younger adults. First, to account for potential age differences in mean levels of affect, affective composites were z-scored within each individual. Then, using HLM, the first set of analyses examined age differences in affective

response that was subsequent to a bout of physical activity following procedures in prior studies (Liao et al., 2017; Kim et al., 2018). The daily physical activity variable represented absence or presence of a self-reported or actigraphy-defined daily physical activity bout prior to the prompt. The daily physical activity variable was included as a fixed and random effect and represented a level 1 (prompt level) variable while age group represented level 2 (person level) variable. The daily physical activity variable was entered as a random effect as well.

The primary outcome measure was the HAP affect composite while age group and daily physical activity were entered as independent variables. The intraclass correlation coefficient (ICC) for raw HAP affect was 0.55 which means that there was slightly more variability at the between-person level than the within-person level. The ICC was similar value for all other affective composites. As mentioned above, to account for potential age differences in mean levels of affect, affective composites z-scored within each individual. In addition, the models did not significantly differ if daily physical activity variable was entered as a random effect or not, hence, it was excluded from the subsequent analyses due to model simplicity. The final model included only significant covariates, as described above. Planned exploratory models were conducted with other affective composites as outcomes following the same procedure (i.e., LAP, HAN, and LAN affect).

2.8.3 The effect of social context on age differences in affective response to daily physical activity

A second set of analyses examined the hypothesis that engaging in daily physical activity with others will increase high arousal positive affect more than being alone, particularly for older adults. Social context of daily physical activity (factor variable: alone (0) vs one other person (1) vs group (2)), age group, and daily physical activity variables were entered in the HLM models to examine the main effects, two-way interactions, and the three-way interaction. Subsequent

planned analysis examined whether the relationship to the other person/group (close vs not close) further moderated the association between social context and affective response after daily physical activity. Close relationship was defined as spouse/partner, family, and friends while not close relationship was defined as coworker, stranger and other category (e.g., clients, patients). Additional planned exploratory models examined whether age differences in affective responses to daily physical activity were moderated by other variables (i.e., enjoyment, physical exertion, and physical context).

2.8.4 Mediation of age differences in overall physical activity levels by affective response to daily physical activity

Mediation analysis was done to examine the hypothesis that smaller increase in high arousal positive affect after daily physical activity will mediate the effect of age on overall physical activity levels. The first step examined whether the necessary conditions for mediation were met (i.e., the independent and outcome variable were significantly related to the mediator). Based on current recommendations, a significant association between the independent and the outcome variable was not required to assess for mediation (MacKinnon et al., 2002; Rucker, Preacher, Tormala, & Petty, 2011). In order to conduct a linear regression, a summary statistic for HAP affective response to daily physical activity was created. The average HAP affect across prompts with daily physical activity endorsement was computed for each individual. One individual was found to have only one prompt with endorsement of daily physical activity when daily physical activity was determined via self-reported, hence, that participant was excluded from those models involving the average affective composite across prompts with daily physical activity endorsement. If the associations between the independent (age group) and the outcome (overall physical activity levels estimate MVPA) variable with the mediator (HAP affect) were found to be significant, a mediation analysis (Tingley et al., 2013) examined whether the affective

responses to daily physical activity mediated age effects on overall physical activity levels. The R package “mediation” also computed bootstrapped confidence intervals of the indirect effect (Tingley et al., 2013).

2.8.5 Internal consistency of exercise goals.

First, Cronbach’s alpha was calculated for both hedonic and instrumental composite to determine internal consistency of the composites. Internal consistency was 0.94 for the hedonic composite and 0.91 for the instrumental composite, hence, the composites were used to create a proportion score. The proportion score was calculated by subtracting hedonic composite from instrumental composite and dividing by the instrumental goals composite to examine whether greater orientation towards hedonic versus instrumental goals is more relevant for the affective responses and physical activity levels. Higher scores indicated greater endorsement of instrumental goals, while lower (i.e., negative) scores indicated greater endorsement of hedonic goals.

2.8.6 Age differences in exercise goals

In order to examine the hypothesis that older adults will endorse instrumental goals to a greater extent than hedonic goals compared to younger adults, a t-test was done with age group as the independent variable and hedonic versus instrumental goals orientation score as the dependent variable. Additionally, t-tests were done separately for the hedonic goals and instrumental goals.

2.8.7 Mediation of age differences in overall physical activity levels by exercise goals

Mediation analysis was done to examine the hypothesis that greater endorsement of instrumental goals will mediate the effect of age on overall physical activity levels. The first step examined whether the necessary conditions for mediation were met (i.e., the independent and outcome variable were significantly related to the mediator). Based on current recommendations, a

significant association between the independent and the outcome variable was not required to assess for mediation (MacKinnon et al., 2002; Rucker, Preacher, Tormala, & Petty, 2011). If the associations between the independent (age group) and the outcome (MVPA) variable with the mediator (exercise goal orientation) were found to be significant, a mediation analysis (Tingley et al., 2013) examined whether the endorsement of exercise goals mediated age effects on overall physical activity levels. The R package “mediation” also computed bootstrapped confidence intervals of the indirect effect (Tingley et al., 2013).

2.8.8 Association between exercise goals, HAP affect, and overall physical activity levels

Linear regression was performed to examine the hypothesis that, collapsed across age, a stronger association between HAP affect and overall physical activity levels will be present with greater endorsement of hedonic goals compared to instrumental goals. Hedonic versus instrumental goals orientation score and average HAP affective response to daily physical activity bouts, as well as their interaction, were entered as independent variables. Overall physical activity levels (MVPA) estimated via actigraphy served as the outcome variable. A planned exploratory analysis examined whether this association differs in younger versus older adults.

2.8.9 Outliers

For HLM models, case-level outliers were assessed for each of the outcomes and defined as residuals of the full model that were three standard deviations above or below the residual mean. In the second step, these identified outliers were examined in terms of their influence on the model results. If outliers were determined to have Cook’s D value greater than the cut off value of $4/n$ (with n representing number of observations), then separate models were conducted with and without these identified outliers. Results were similar unless otherwise noted in the Results section.

Chapter 3: Results

3.1 Descriptive Statistics

See Table 1 for summary of demographic characteristics and main outcomes.

Table 1 Demographic Characteristics of Participants and Outcomes

	Younger Adults	Older Adults
N	47	47
Age (mean, SD, range)	20±1 (18-23)	67±6 (59-88)*
Gender (F/M)	38/9	38/9
Race/Ethnicity (Asian/Black/White/Hispanic/ More than one race)	14/4/23/8/3	1/6/39/1/0
Education (mean, SD, range)	14±1 (12-17)	17±2 (12-22)*
Health (mean, SD, range)	0.02±0.15 (0-1)	0.33±0.56 (0-2)*
HAP affect (mean, SD, range)	2.08±0.97 (1-5)	1.98±0.92 (1-5)*
LAP affect (mean, SD, range)	2.88±0.87 (1-5)	3.47±0.85 (1-5)*
HAN affect (mean, SD, range)	1.77±0.73 (1-4.67)	1.18±0.44 (1-5)*
LAN affect (mean, SD, range)	2.12±0.89 (1-5)	1.36±0.57 (1-4)*
EMA response rate (mean, SD, range)	84.3±8.5 (62.9-97.1)	79.2±17.9 (20-100)
Actigraphy valid days (mean, SD, range)	6.23±1.51 (2-8)	6.83±0.87 (3-8)

*denotes significant difference between younger and older adults, 3 younger adults were missing information about race and 2 older adults were missing information about ethnicity. HAP = High arousal positive; LAP = Low arousal positive; HAN = High arousal negative; LAN = Low arousal negative.

3.2 Age differences in affective response to daily physical activity

3.2.1 Age differences in HAP affective response to daily physical activity

There was not an age difference in HAP affect ($p=0.102$), see Table 2. As expected, HAP affect was higher after bouts of daily physical activity compared to periods without daily physical activity ($p<0.001$), see Figure 1. However, the association between daily physical activity and HAP did not differ between age groups ($p=0.138$). The results were the same when significant covariates (i.e., day of the week and delay between the activity and the prompt) were entered into the model, see Table 3. See Table 4 for results of the non-significant covariates. Significant day of the week variable indicated that HAP affect was higher during the weekend (Friday and Saturday) compared to the weekdays. Significant delay between the activity and the prompt indicated that HAP affect was lower with longer delay. The results were the same when daily physical activity was defined via actigraphy instead of self-report, see Table 2. However, when outliers were removed, in the actigraphy-defined model with the significant covariate, daily physical activity was not associated with higher HAP affect ($\beta=0.09$, $SE=0.06$, $p=0.115$).

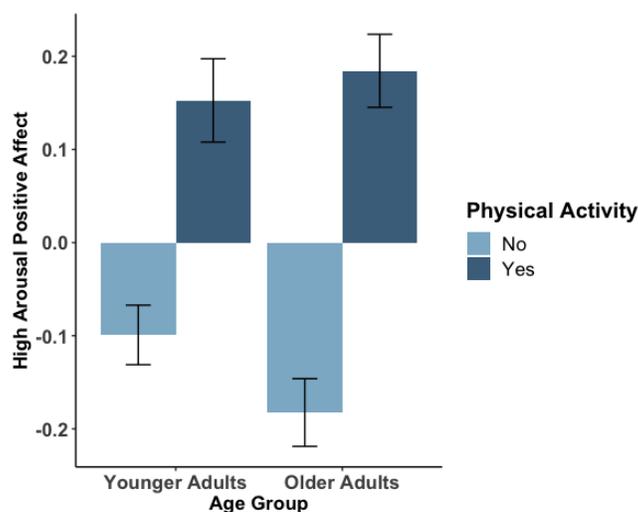


Figure 1 HAP affect across prompts with and without daily physical activity in younger and older adults

Table 2 HAP affect across age groups and prompts with and without daily physical activity in models without covariates

High Arousal Positive Affect						
<i>Predictors</i>	Self-reported model			Actigraphy-defined model		
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>
(Intercept)	-0.10	-0.17 – -0.03	0.003	-0.06	-0.13 – 0.01	0.080
Age Group	-0.08	-0.18 – 0.02	0.102	-0.00	-0.11 – 0.10	0.932
Daily Physical Activity	0.26	0.15 – 0.36	<0.001	0.19	0.07 – 0.31	0.002
Age Group x Daily Physical Activity	0.11	-0.04 – 0.26	0.138	-0.06	-0.22 – 0.10	0.485

Note: bold = significant at $p < .05$. Self-reported = participants endorsed whether they engaged in daily physical activity; actigraphy-defined = daily physical activity was estimated via actigraphy

Table 3 HAP affect across age groups and prompts with and without daily physical activity in models with covariates

High Arousal Positive Affect						
<i>Predictors</i>	Self-reported model			Actigraphy-defined model		
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>
(Intercept)	-0.21	-0.33 – -0.09	0.001	-0.23	-0.35 – -0.11	<0.001
Age Group	-0.08	-0.18 – 0.02	0.124	-0.01	-0.10 – 0.09	0.908
Daily Physical Activity	0.27	0.16 – 0.37	<0.001	0.16	0.04 – 0.27	0.008
Age Group x Daily Physical Activity	0.11	-0.03 – 0.26	0.129	-0.04	-0.19 – 0.12	0.650
Tuesday	0.05	-0.08 – 0.19	0.450	0.12	-0.07 – 0.31	0.230
Wednesday	0.07	-0.07 – 0.20	0.339	0.11	-0.06 – 0.29	0.217
Thursday	0.12	-0.02 – 0.25	0.093	0.15	-0.03 – 0.33	0.110
Friday	0.33	0.19 – 0.46	<0.001	0.35	0.19 – 0.51	<0.001
Saturday	0.36	0.22 – 0.49	<0.001	0.40	0.23 – 0.57	<0.001
Sunday	0.13	-0.01 – 0.27	0.060	0.16	0.02 – 0.31	0.026
Delay b/w Activity and Prompt	-0.02	-0.04 – -0.00	0.040			

Note: bold = significant at $p < .05$. Self-reported = participants endorsed whether they engaged in daily physical activity; actigraphy-defined = daily physical activity was estimated via actigraphy

Table 4 Non-significant covariates in the model of HAP affective response to daily physical activity

<i>Predictors</i>	High Arousal Positive Affect		
	<i>Estimates</i>	<i>SE</i>	<i>p</i>
Time of Day (Morning)	0.08	0.97	0.934
Time of Day (Afternoon)	0.04	0.97	0.971
Time of Day (Evening)	0.07	0.97	0.942
Order in Study	-0.0002	0.001	0.825
Education	-0.0002	0.01	0.989
Gender	0.002	0.05	0.968
Depressive Symptoms	0.001	0.003	0.764
Anxiety Symptoms	0.0002	0.003	0.960
Typical HAP	-0.003	0.01	0.725

3.2.2 The effect of social context on age differences in HAP affective response to daily physical activity

Social context was not found to moderate the association between age and HAP affective response subsequent to daily physical activity ($p=0.556$, $p=0.082$, see Table 5). Due to the trend in the three-way interaction, additional post-hoc analysis explored whether being in a group moderated age differences in affective response to daily physical activity.⁴ The post-hoc analysis found a trend for only older adults to report less HAP affect following daily physical activity in a group ($p=0.075$). Next, the non-significant three-way interactions and non-significant two-way Physical Activity x Social Context interaction were dropped from the model. When there was endorsement of an activity with another person compared to alone, older adults showed lower

⁴ In the full model, greater HAP affective response after daily physical activity was reported in older adults compared to younger adults ($p=0.020$).

HAP affect while younger adults showed higher HAP affect (Age Group x Person: $p=0.002$) see Table 6 and see Figure 2. In addition, there was a trend for greater HAP affective response to be associated with daily physical activity for older adults relative to younger adults in the final model ($p=0.052$), see Table 6. The results were the same with significant covariates (i.e., day of the week, delay between the activity and the prompt) entered into the model.

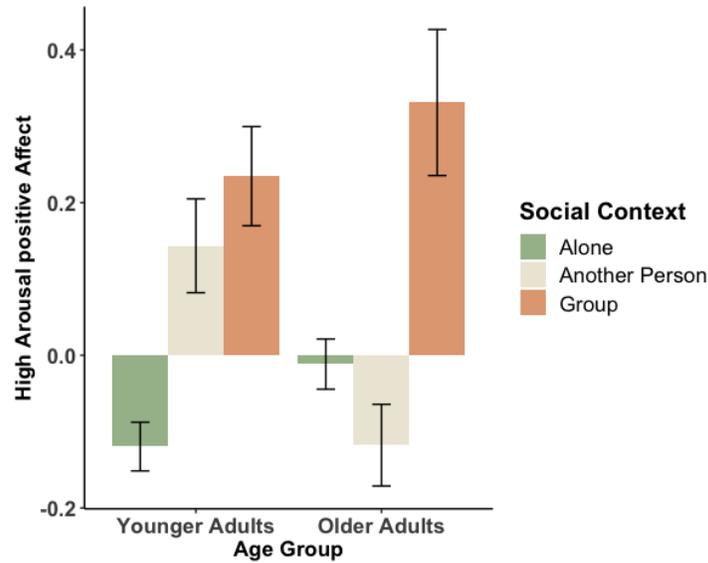


Figure 2 HAP affect across social context in younger and older adults

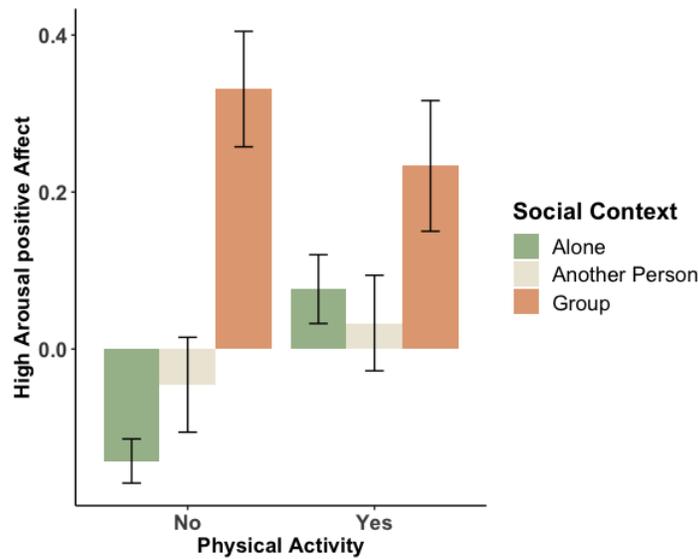


Figure 3 HAP affect across social context in prompts with and without actigraphy-defined daily physical activity

In the actigraphy-defined final model, higher HAP affect was not observed for daily physical activity bouts done with a group relative to other activities done in a group (Daily Physical Activity x Group: $p=0.017$), see Figure 3 and Table 6. The effect of the endorsement of daily physical activity on HAP affect in group social context was not observed in the self-reported model ($p=0.801$).

Table 5 The effect of social context on HAP affective response to self-reported and actigraphy-defined daily physical activity full models

<i>Predictors</i>	High Arousal Positive Affect						
	Self-reported model			Actigraphy-defined model			
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>	
(Intercept)	-0.18	-0.27 – -0.10	<0.001	-0.20	-0.29 – -0.11	<0.001	
Age Group	-0.03	-0.15 – 0.10	0.646	0.12	-0.01 – 0.24	0.063	
Person	0.20	0.01 – 0.40	0.039	0.30	0.10 – 0.51	0.003	
Group	0.29	0.10 – 0.49	0.003	0.46	0.25 – 0.67	<0.001	
Daily Physical Activity	0.18	0.04 – 0.31	0.010	0.27	0.11 – 0.43	0.001	
Age Group x Person	-0.29	-0.56 – -0.01	0.039	-0.43	-0.71 – -0.14	0.004	
Age Group x Group	0.15	-0.19 – 0.49	0.383	0.01	-0.37 – 0.39	0.966	
Age Group x Daily Physical Activity	0.22	0.03 – 0.40	0.020	-0.12	-0.33 – 0.09	0.252	
Daily Physical Activity x Person	0.08	-0.19 – 0.35	0.545	-0.18	-0.49 – 0.13	0.260	
Daily Physical Activity x Group	0.13	-0.15 – 0.41	0.369	-0.30	-0.61 – 0.01	0.061	
Age Group x Daily Physical Activity x Person	-0.11	-0.48 – 0.26	0.556	0.17	-0.24 – 0.58	0.416	
Age Group x Daily Physical Activity x Group	-0.40	-0.85 – 0.05	0.082	-0.05	-0.54 – 0.44	0.846	

Note: bold = significant at $p<.05$. Self-reported = participants endorsed whether they engaged in daily physical activity; actigraphy-defined = daily physical activity was estimated via actigraphy

Table 6 The effect of social context on HAP affective response to self-reported and actigraphy-defined daily physical activity final models

High Arousal Positive Affect							
<i>Predictors</i>	Self-reported model			Actigraphy-defined model			
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>	
(Intercept)	-0.20	-0.28 – -0.12	<0.001	-0.18	-0.26 – -0.10	<0.001	
Age Group	0.00	-0.11 – 0.12	0.979	0.08	-0.02 – 0.19	0.118	
Person	0.24	0.09 – 0.39	0.002	0.28	0.09 – 0.47	0.004	
Group	0.34	0.18 – 0.51	<0.001	0.47	0.27 – 0.66	<0.001	
Daily Physical Activity	0.22	0.11 – 0.32	<0.001	0.20	0.09 – 0.31	<0.001	
Age Group x Person	-0.34	-0.55 – -0.13	0.002	-0.37	-0.60 – -0.14	0.002	
Age Group x Group	-0.05	-0.31 – 0.21	0.717	-0.03	-0.32 – 0.25	0.814	
Age Group x Daily Physical Activity	0.15	-0.00 – 0.30	0.052				
Daily Physical Activity x Person				-0.08	-0.28 – 0.13	0.452	
Daily Physical Activity x Group				-0.29	-0.53 – -0.05	0.017	

Note: bold = significant at $p < .05$. Self-reported = participants endorsed whether they engaged in daily physical activity; actigraphy-defined = daily physical activity was estimated via actigraphy

Collapsed across the age groups, HAP affect was higher when participants engaged in daily physical activity with someone close compared to someone not close ($\beta=0.35$, $SE=0.13$, $p=0.007$). This effect did not vary by age. See **Appendix A** for results of planned exploratory models which examined whether other factors (physical context, self-reported physical exertion, and self-reported enjoyment) moderated age differences in HAP affective responses to daily physical activity.

3.2.3 Age differences in LAP, HAN, and LAN affective responses to daily physical activity

The age groups did not differ in their LAP, HAN, and LAN affective response ($p=0.652$, $p=0.490$, 0.883), see Tables 7-11. LAP and HAN affect did not differ whether physical activity was endorsed or not ($p=0.243$, $p=0.930$) and this result did not vary between the age groups ($p=0.666$, $p=0.833$), see Tables 7-9. LAN was significantly lower after bouts of daily physical activity than after other activities ($p<0.001$). However, this effect did not differ by age group ($p=0.399$), see Figure 4. When daily physical activity was defined via actigraphy, LAN affect did not differ whether physical activity was done or not ($p=0.513$), see Table 7. The results were the same when significant covariates were entered into the model, see Tables 8 and 11.

Table 7 LAP affect across age groups and prompts with and without daily physical activity in models without covariates

<i>Predictors</i>	Low Arousal Positive Affect					
	Self-reported model			Actigraphy-defined model		
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>
(Intercept)	0.02	-0.04 – 0.09	0.465	0.01	-0.06 – 0.07	0.838
Age Group	0.02	-0.08 – 0.12	0.652	0.05	-0.05 – 0.15	0.326
Daily Physical Activity	-0.06	-0.17 – 0.04	0.243	-0.02	-0.14 – 0.10	0.716
Age Group x Daily Physical Activity	-0.03	-0.18 – 0.12	0.666	-0.10	-0.26 – 0.06	0.240

Note: bold = significant at $p<.05$. Self-reported = participants endorsed whether they engaged in daily physical activity; actigraphy-defined = daily physical activity was estimated via actigraphy

Table 8 LAP affect across age groups and prompts with and without daily physical activity in models with covariates

Low Arousal Positive Affect						
<i>Predictors</i>	Self-reported model			Actigraphy-defined model		
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>
(Intercept)	-0.02	-0.13 – 0.10	0.784	-0.03	-0.14 – 0.09	0.644
Age Group	0.02	-0.08 – 0.12	0.632	0.04	-0.06 – 0.14	0.443
Daily Physical Activity	-0.06	-0.16 – 0.05	0.294	-0.04	-0.16 – 0.08	0.498
Age Group x Daily Physical Activity	-0.04	-0.19 – 0.11	0.644	-0.07	-0.24 – 0.09	0.369
Tuesday	-0.05	-0.19 – 0.08	0.442	-0.05	-0.19 – 0.09	0.498
Wednesday	-0.07	-0.21 – 0.06	0.283	-0.05	-0.19 – 0.09	0.461
Thursday	-0.03	-0.17 – 0.11	0.660	-0.02	-0.17 – 0.12	0.736
Friday	0.12	-0.02 – 0.26	0.083	0.12	-0.02 – 0.26	0.103
Saturday	0.17	0.03 – 0.31	0.016	0.16	0.02 – 0.31	0.028
Sunday	0.14	0.00 – 0.28	0.048	0.16	0.01 – 0.31	0.032

Note: bold = significant at $p < .05$. Self-reported = participants endorsed whether they engaged in daily physical activity; actigraphy-defined = daily physical activity was estimated via actigraphy

Table 9 HAN affect across age groups and prompts with and without daily physical activity

High Arousal Negative Affect						
<i>Predictors</i>	Self-reported model			Actigraphy-defined model		
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>
(Intercept)	0.03	-0.04 – 0.10	0.370	0.03	-0.04 – 0.10	0.392
Age Group	-0.01	-0.11 – 0.10	0.883	-0.03	-0.14 – 0.07	0.543
Daily Physical Activity	-0.001	-0.11 – 0.10	0.930	-0.09	-0.21 – 0.03	0.127
Age Group x Daily Physical Activity	0.02	-0.14 – 0.17	0.833	0.10	-0.07 – 0.27	0.238

Note: bold = significant at $p < .05$. Self-reported = participants endorsed whether they engaged in daily physical activity; actigraphy-defined = daily physical activity was estimated via actigraphy

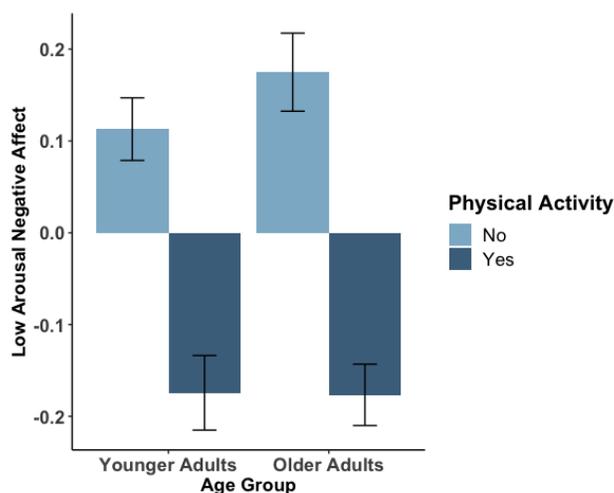


Figure 4 LAN affect across prompts with and without self-reported physical activity in younger and older adults

Table 10 LAN affect across age groups and prompts with and without daily physical activity in models without covariates

<i>Predictors</i>	Low Arousal Negative Affect					
	Self-reported model			Actigraphy-defined model		
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>
(Intercept)	0.11	0.05 – 0.18	0.001	0.01	-0.05 – 0.08	0.714
Age Group	0.06	-0.04 – 0.16	0.223	0.02	-0.08 – 0.12	0.678
Daily Physical Activity	-0.29	-0.39 – -0.18	<0.001	-0.04	-0.16 – 0.08	0.513
Age Group x Daily Physical Activity	-0.06	-0.21 – 0.09	0.399	-0.03	-0.19 – 0.13	0.714

Note: bold = significant at $p < .05$. Self-reported = participants endorsed whether they engaged in daily physical activity; actigraphy-defined = daily physical activity was estimated via actigraphy

Table 11 LAN affect across age groups and prompts with and without daily physical activity in models with covariates

Low Arousal Negative Affect						
<i>Predictors</i>	Self-reported model			Actigraphy-defined model		
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>
(Intercept)	-0.01	-0.09 – 0.07	0.833	-0.09	-0.17 – -0.01	0.022
Age Group	0.04	-0.06 – 0.15	0.409	0.01	-0.09 – 0.11	0.800
Daily Physical Activity	-0.34	-0.45 – -0.23	<0.001	-0.06	-0.18 – 0.06	0.338
Age Group x Daily Physical Activity	-0.07	-0.22 – 0.09	0.394	-0.02	-0.19 – 0.14	0.777
Delay b/w Activity and Prompt	0.06	0.04 – 0.09	<0.001	0.04	0.03 – 0.06	<0.001

Note: bold = significant at $p < .05$. Self-reported = participants endorsed whether they engaged in daily physical activity; actigraphy-defined = daily physical activity was estimated via actigraphy

3.2.4 Summary

Overall, self-reported and actigraphy-defined daily physical activity was found to be associated with greater HAP affect compared to other activities. Self-reported daily physical activity was associated with lower LAN affect, however, LAN affect did not significantly differ whether actigraphy-defined daily physical activity was present or not. No age differences were observed in the affective responses. See **Appendix C** for the post-hoc exploration of the effect of age on affective response in older adult group only. HAP affective response to daily physical activity across age groups did not differ based on the social context. However, older adults showed less HAP affect when doing any activity with another person versus alone while younger adults showed more HAP affect when doing any activity with another person versus alone. In the actigraphy-defined daily physical activity model, there was an effect of social context on affective response to daily physical activity, such that there was no benefit of doing daily

physical activity in a group compared to other activities in a group relative to the benefit that was observed when doing daily physical activity alone compared to doing any other activity alone.

Taken together, there was no support for the hypothesis that affective responses to daily physical activity would vary by age and/or social context.

3.3 Affective response and overall physical activity levels

3.3.1 Mediation of age differences in overall physical activity levels by affective response to daily physical activity

As outlined in the statistical analyses section above, first linear regression models tested the association of the independent variable (i.e., Age Group) and the outcome (i.e., MVPA as the estimate of overall physical activity levels) with the mediator (i.e., HAP affect averaged across all of the prompts with the daily physical activity endorsement). In line with the HLM results, controlling for gender and education, the age groups did not differ in average HAP affect after a bout of daily physical activity ($\beta=0.09$, $SE=0.08$, $CI [-0.06, 0.24]$, $p=0.237$). In addition, HAP affect was not significantly associated with MVPA ($\beta=0.03$, $SE=0.04$, $CI[-0.06, 0.12]$, $p=0.488$). Mediation analysis was not done due to the lack of significant associations. Notably, contrary to expectations, older adults showed greater engagement in MVPA compared to younger adults ($\beta=0.09$, $SE=0.03$, $CI [0.02, 0.15]$, $p=0.007$), see Figure 5.

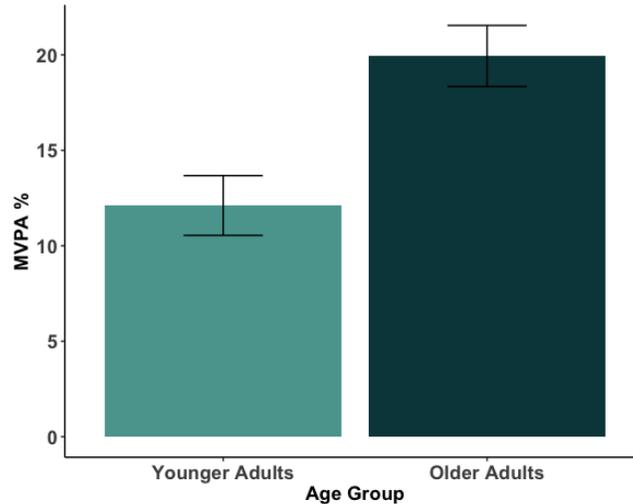


Figure 5 Age differences in average percentage of time spent in MVPA relative to total wear time. In terms of other affective composites, MVPA was not associated with LAP, HAN, or LAN affect subsequent to daily physical activity bouts (all p 's > 0.199). The results were the same when the endorsement of daily physical activity was determined via actigraphy instead of the self-report.

3.3.2 Summary

Contrary to the expectations, older adults were found to have greater engagement in overall physical activity levels (MVPA) over the week relative to younger adults. As mentioned in the Summary 3.2.3, HAP affective response to a bout of daily physical activity did not vary by age group. In addition, none of the affective composites were found to predict the overall physical activity levels. Thus, there was no support for the hypothesis that HAP affect following endorsement of daily physical activity would mediate age differences in overall physical activity levels.

3.5 Exercise Goals

3.5.1 Age differences in exercise goals

As expected, older adults showed a greater orientation towards instrumental goals relative to hedonic goals compared to younger adults ($t=-2.25$, $df=92.9$, $p=0.027$), see Figure 9. Older adults endorsed instrumental goals to a significantly greater extent than younger adults ($t=-5.35$, $df=92.9$, $p<0.001$). Younger and older adults did not differ in their endorsement of hedonic goals ($t=-0.90$, $df=92.9$, $p=0.370$).

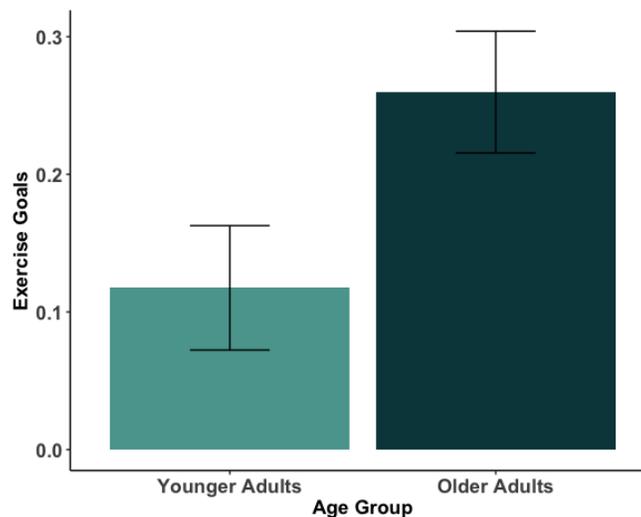


Figure 6 Age differences in exercise goals orientation. Higher score indicates greater orientation towards instrumental goals relative to hedonic goals

3.5.2 Mediation of age differences in overall physical activity levels by exercise goals

As outlined in the statistical analyses section above, the first linear models tested the associations of the independent variable (i.e., Age Group) and the outcome (i.e., MVPA) variable with the mediator (i.e., exercise goals orientation). As noted, older adults showed greater orientation towards instrumental goals relative to hedonic goals compared to younger adults. However, goals orientation did not significantly predict MVPA, controlling for gender, education, and wear time ($\beta=-0.004$, $SE=0.04$, $CI [-0.08, 0.07]$, $p=0.912$). Mediation analysis was not done due to the lack of relevant associations.

3.5.3 Association between exercise goals, HAP affect, and overall physical activity levels

The association between HAP affective response and MVPA was not significantly stronger with greater orientation towards hedonic goals ($\beta=-0.17$, $SE=0.14$, $CI [-0.49, 0.12]$, $p=0.250$). In addition, the interactions between other affective composites (LAP, HAN, and LAN affect) and exercise goal orientation were not significant in predicting MVPA (all p 's > 0.429). See **Appendix B** for post-hoc analyses that examined whether exercise goals predicted affective response to daily physical activity.

3.5.4 Summary

Older adults showed greater orientation towards instrumental goals relative to hedonic goals compared to younger adults. However, exercise goals orientation did not significantly predict overall physical activity levels (MVPA), hence, a mediation analysis was not done. Furthermore, a stronger association between high arousal positive affect and overall physical activity levels with greater endorsement of hedonic goals was not observed. Thus, there was no support for the hypothesis that greater orientation towards instrumental goals relative to hedonic goals would mediate age differences in overall physical activity levels. In addition, there was no support for the hypothesis that exercise goals orientation would moderate the association between affective response to daily physical activity and overall physical activity levels.

Chapter 4: Discussion

The goal of this project was to examine the role of affective responses and exercise goals in sustained physical activity engagement in younger and older adults. In terms of age differences in affective response to daily physical activity, I hypothesized that older adults would experience smaller increase in high arousal positive affect after bouts of physical activity in daily life compared to younger adults. I also hypothesized that engaging in daily physical activity with others would increase high arousal positive affect more than being alone, particularly for older adults. Finally, I hypothesized that smaller increase in high arousal positive affect after daily physical activity would mediate the effect of age on overall physical activity levels across the week. Focusing on exercise goals, I hypothesized that older adults would endorse instrumental goals to a greater extent than hedonic goals compared to younger adults. In addition, I hypothesized that greater endorsement of instrumental goals would mediate the effect of age on overall physical activity levels across the week. Finally, I hypothesized that, collapsed across age, a stronger association between high arousal positive affect and overall physical activity levels would be present with greater endorsement of hedonic goals compared to instrumental goals.

4.1 Age differences in HAP affective response to daily physical activity

Consistent with prior findings, daily physical activity was associated with higher HAP affect relative to other activities (Liao et al., 2015; Ekkekakis et al., 2000; Hogan et al., 2013). Most of the studies that examined the affective response to physical activity/exercise using the affective circumplex were studies of the effects of acute exercise (e.g., Ekkekakis et al., 2003; Hogan et al., 2013; Reed & Ones, 2006). On the other hand, the EMA studies examining the associations

between daily physical activity and affect in everyday life primarily looked at valence collapsed across the dimension of arousal (i.e., positive affect; e.g., Liao et al., 2017; Dunton et al., 2009). To our knowledge, this is one of the first studies that showed that daily physical activity, both defined via self-reported and actigraphy, was associated with greater HAP affect after bouts of physical activity in daily life. While it is likely that daily physical activity increased HAP affect, it is also possible that more HAP affect leads to engagement in daily physical activity. Hence, the potential bidirectional effects and causal relationships between physical activity/exercise and affect in both younger and older adults need to be examined in future work.

However, no age differences were observed in the association between HAP affect and daily physical activity. While the limited number of prior studies comparing directly younger and older adults focused on effects of acute exercise, our results are consistent with the observed age-invariant HAP affective response to acute exercise (e.g., Hogan et al., 2013; Focht et al., 2007). As described by the model (Ekkekakis et al., 2003). It might be that age differences only become apparent at higher intensity levels when people reach the ventilatory threshold. This is harder to capture with the experience sampling method without experimental control of the level of exercise intensity. However, the self-reported perceived intensity did not moderate the age-invariant HAP affect response. Furthermore, a study directly comparing young and older adults found that younger adults showed higher positive affect following light physical activity compared to older adults, but no significant relationship between moderate or vigorous activity and affect in either group (Ready et al., 2009). However, this study used only a subjective measure of physical activity and employed daily assessment of affect and physical activity at the end of the day only. While controlling for the delay between the daily physical activity and the prompt did not change the current results, it could be that the age differences in affective

response are more salient during and immediately post-exercise/physical activity as proposed by the model (Ekkekakis et al., 2000). A study done in older adults by Kanning and colleagues (2015), did not find a significant relationship between daily physical activity and affect that was assessed 10 minutes later.

Furthermore, the effect sizes were also small when the affective responses to daily physical activity were examined only in the older adult group. Results were interpreted with caution and without reference to the significance levels since these post-hoc analyses were likely underpowered. While older adults are shown to have less preference for HAP affect (Scheibe et al., 2013), it is unclear whether that preference would change in the context of daily physical activity and exercise. That is, it is uncertain whether older adults still prefer less HAP affect in response to physical activity/exercise since the HAP affect is induced by an activity that produces physiological cues, and consequently increases arousal, itself. Finally, since older adults from our sample seemed to have represented a more selective group of active individuals, another potential consideration is that they might have shown greater HAP affective response to daily physical activity compared to other samples of older adults.

However, when social context or enjoyment were also present in the self-reported daily physical activity model, we did find that older adults experienced higher HAP affect in response to daily physical activity compared to younger adults. Results should be interpreted with caution considering that this interaction only becomes significant in the presence of other significant interactions and the number of analyses conducted. Overall, older adults might show the same or even greater HAP affective response after daily physical activity. Compared to younger adults, older adults exhibit greater emotion regulation skills (Scheibe et al., 2013). Hence, they might employ these emotion regulation skills following engagement in daily physical activity to

increase their positive affect to the same extent as younger adults or even more. In our study, participants were able to choose their preferred daily physical activities, which might have contributed to the ability of older adults to regulate their emotions. Furthermore, younger and older adults might choose different types of physical activities in their daily life. For example, older adults might be more likely to engage in walking or gardening while younger adults might be more likely to engage in weight training and high intensity sports (e.g., soccer). It remains to be studied whether different types of physical activities elicit differing affective responses across the adulthood, which could be contributing to the lack of age differences observed in this study. Future studies need to replicate this finding and further examine age differences in affective response both during and after bouts of daily physical activity. Overall, we observed age-invariant affective response to daily physical activity which could be due to potentially similar underlying mechanisms of affective response to exercise/physical activity in younger and older adults (Ekkekakis et al., 2013) or due to insufficient power to detect the effect. Furthermore, the lack of age differences in affective response might signify that other factors play a more prominent role in the age differences in overall physical activity levels that are usually observed.

4.2 The effect of social context on age differences in HAP affective response to daily physical activity

Social context did not moderate age-invariant HAP affective response subsequent to daily physical activity bouts. This is in contrast with a prior study that found an association between social context and higher positive affect following daily physical activity (Dunton et al., 2015). The age of that sample ranged from 25-73 years old but excluded individuals who regularly engaged in over 150 minutes of MVPA and consisted of a high percentage of obese/overweight participants (61%). It is possible that engaging in daily physical activity with someone else/group

is more strongly associated with positive affect for more inactive people compared to our more active sample. More studies need to be done that examine the effect of social context on affective response to daily physical activity in younger and older adults.

There was an overall effect of older adults reporting less HAP affect collapsed across activities (daily physical activity or otherwise) with another person compared to alone. Interestingly, post-hoc analysis found that, again collapsed across activities, engaging in any activity with another person also increased LAP affect for older adults compared to doing the activity alone.

Considering that older adults prefer and experience less HAP affect and more LAP affect (Scheibe et al., 2013), as it was shown in this study as well, it might be that they overall seek out activities with other people that will increase LAP affect. This highlights the importance of examining both valence and arousal dimensions of positive affect.

In the actigraphy-defined daily physical activity model, the results suggested that participants did not show significantly higher HAP affect from doing daily physical activity in a group compared to other activities done with a group. The reporting of the context is likely more in accordance with the self-report of daily physical activity rather than actigraphy. Since actigraphy can detect light physical activity that participants were not aware of or forgot to report, it is possible that the discrepancy in the results is stemming from this difference. The higher HAP affect subsequent to doing daily physical activity in a group relative to other activities in the group might be more poignant when the activity was noticed and remembered. Taken together, social context was not found to be significantly associated with HAP affect after daily physical activity, however, it remains to be examined whether engaging in daily physical activity with someone else might be more advantageous for less active individuals or individuals who are in the phase of adopting regular, sustained physical activity engagement.

4.3 The effect of other moderators on age differences in HAP affective response to daily physical activity

See **Appendix A** for results of the other moderators on age differences in affective responses to daily physical activity. One important moderator of HAP affective response to self-reported daily physical activity was, perhaps not surprisingly, enjoyment. However, given the number of analysis conducted, the results should be interpreted with caution. Overall, greater enjoyment was associated with greater HAP affect across any type of activity. In addition, older adults reported significantly higher levels of enjoyment across any activity, but also during daily physical activity specifically, compared to younger adults. However, the effect of enjoyment during daily physical activity seemed to be particularly strong in younger adults since they showed an even greater association between enjoyment and HAP affect following daily physical activity compared to other activities. This is in line with prior work that examined this question after a bout of acute exercise in younger adults (Raedeke et al., 2007), however, age differences have not been thoroughly examined before. Based on this finding, self-reported enjoyment during daily physical activity might be important for younger adults to experience greater HAP affect after daily physical activity. This finding was not observed in the actigraphy-defined physical activity model. Since enjoyment represented a perceived feeling in our study, self-reported enjoyment might be particularly relevant when younger adults notice and remember the engagement in daily physical activity. Overall, this result tentatively suggest that enjoyment of daily physical activity might be relevant across the adulthood, however, it might be more important for younger adults to intentionally engage in daily physical activity that they will enjoy. Future studies can consider examining the causal relationships between enjoyment, affect, and physical activity engagement.

In addition, physical context was a moderator of age differences in HAP affective response to actigraphy-defined daily physical activity. The results suggested that younger adults exhibited higher HAP affect subsequent to engaging in daily physical activity outdoors when it was defined via actigraphy. This result is consistent with prior findings of a relationship between doing the physical activity outdoors and affect (Dunton et al., 2015). Interestingly, this was only observed in the actigraphy-defined physical activity model but not the self-reported physical activity model. Hence, this finding should also be interpreted with caution, especially since context of an activity is only self-reported. As mentioned above, it is possible that actigraphy can detect light physical activity that participants were not classifying as daily physical activity at the time of the report, hence, younger adults might experience a stronger association between affect and light daily physical activity outdoors. Future work can further examine whether physical context differs based on the method of assessment and intensity of the activity in younger versus older adults.

4.4 Affective response and overall physical activity levels

Contrary to what was expected, older adults showed greater engagement in moderate-to-vigorous physical activity and greater overall physical activity levels during the week of experience sampling compared to younger adults. This finding might stem primarily from sample differences. It is possible that a highly selective group of older adults with already high levels of MVPA was willing to sign up for a physical activity study, particularly during the COVID-19 pandemic. Compared to other estimates of MVPA in older adults, this sample engaged in overall physical activity slightly or substantially more (119.64 min/day) than other samples of older adults (e.g., Artese et al., 2017: 113.3 min/day; Law et al., 2018: 86 min/day). As for the younger adults, our sample consisted of college students who seemed to have engaged in overall physical

activity (72.66 min/day) approximately on par with community samples of younger adults (Dominick et al., 2016: 69.4 min/day; Vanhelst et al., 2012: 87.68/day) or even more than another sample of college students (Dinger et al, 2006: 11.1 min/day). However, these studies vary in their calculation and reporting of MVPA estimates, and whether they excluded sedentary individuals, which makes direct comparison across studies difficult. In addition, the data collection for this study occurred during the pandemic. There is some evidence to suggest that overall leisure-time physical activity levels decreased during the pandemic (Mutz & Gerke, 2021), however, more so in community older adults than community younger adults. On the other hand, there seems to be a significant decline in overall physical activity levels among college students in particular (Wilson et al., 2021; Barkley et al., 2020). Hence, future studies need to again directly compare overall physical activity levels in younger and older adults to determine the potential impact of the pandemic.

In the current study, HAP affective response to daily physical activity did not predict overall physical activity levels (MVPA) in either age group. Prior work indicated mixed findings in terms of post-acute exercise affect predicting overall physical activity levels (Rhodes & Kates, 2015). Furthermore, it seems that the affective response during rather than post-acute exercise may be more predictive of levels of physical activity (Rhodes & Kates, 2015). In addition, one prior EMA study found an association between affect during daily physical activity and overall physical activity levels at a 6-month and 12-month follow-up (Liao et al., 2017). However, this study only examined affect during daily physical activity, with a relatively small number of prompts, and was done primarily in young and middle-age adults (mean age 39.8). Taken together, it might be that affect during daily physical activity is more predictive of overall physical activity levels compared to the affect after daily physical activity. This potential

implication is still relevant for the proposed causal chain that positive affective response to physical activity/exercise leads to greater adherence. However, it might be the case that additional factors would need to be incorporated as independent or moderating factors into the model. For example, one way to further distinguish between the impact of the affect during versus after bouts of daily physical activity is to examine the recall of the affective experience the following time people engage in physical activity, or even at a 3- or 6-month follow-up. It would be important to examine whether younger and older adults are differentially accurate in recalling their affective response during versus after daily physical activity and how this might impact their intentions to engage in sustained, regular physical activity. Finally, another potentially important aspect to consider is affective judgment (i.e., judgments about the overall pleasure/displeasure, enjoyment, and feeling states expected from enacting physical activity) which has been linked to overall physical activity levels (Rhodes et al., 2009) and whether affective judgment during versus after daily physical activity could moderate the association with overall physical activity levels.

In addition, while HAP affective response was not significantly associated with MVPA, the pattern was in the predicted direction, with greater HAP affect corresponding to more MVPA. Hence, another possibility is that the effect size is small and greater sample size is needed to detect the significant associations. Finally, the estimate of average HAP affective response was aggregated across different intensities of daily physical activity. Most of the aforementioned studies examined specifically affect after moderate-intensity acute exercise. Hence, it remains to be studied whether affective response after physical activities of different intensities is differentially associated with MVPA, especially when considering that older adults are likely to engage more frequently in light physical activity relative to moderate or vigorous physical

activity (e.g., Gine-Garriga et al., 2020). Taken together, affective response after daily physical activity might be limited or play a smaller role in the models of exercise/physical activity adherence. However, as outlined above, further work needs to be done to better understand the role of affective response both during and after daily physical activity in regular physical activity engagement in younger and older adults.

4.5 Age differences in LAP, HAN, and LAN affective responses to daily physical activity, and associations with overall physical activity levels

In terms of other affective composites, daily physical activity was found to be associated with less LAN affect but had no effect on HAN and LAP affect across age groups. Notably, the smaller LAN affect following daily physical activity bouts was only observed in the self-reported model. It might be the case that light physical activity detected by actigraphy is not sufficient to impact LAN affect or that people need to be aware of the engagement in daily physical activity to show less LAN affect. Hence, these results should be interpreted with caution and also considering the possibility that people are more likely to choose to engage in daily physical activity when they feel less sluggish, bored, and sleepy. Overall, there is a dearth of studies that have examined all of the aspects of the affective circumplex, with most examining only positive affect or, more specifically, HAP affect. One study found that LAP affect decreased after acute exercise in younger adults but not for older adults (Hogan et al., 2013) while we observed no change in LAP affect across age groups. The differences in the results might stem from having prescribed moderate-intensity acute exercise versus self-chosen daily activities in our study.

Mixed findings have been observed in terms of the impact of daily physical activity on negative affect (for review: Liao et al, 2015). However, there is less consistency in use of the negative

affective terms across the studies and each study might have sampled differentially across the high and low arousal dimension of negative affect. For example, PANAS is commonly used and more likely to sample across high arousal affective terms (Ekkekakis et al., 2003). This finding again highlights the importance of considering both arousal and valence dimension in estimation of the effects of daily physical activity on affect. In addition, some of the LAN affective terms (e.g., sleepy, sluggish) are relatively similar to the energetic arousal scale (e.g., awake, fatigued) that has been frequently used in assessing impact of daily physical activity on affect (e.g., Kanning & Slicht, 2010) with energetic arousal increasing after physical activity in daily life. Finally, no age differences were observed in the LAP, HAN, and LAN affective responses to daily physical activity. The model proposed by Ekkekakis and colleagues (2013) discusses increase in negative affect during exercise, hence, it might be the case that age differences in LAN and HAN, in particular, would be more apparent during daily physical activity. Future work needs to further examine the impact of prescribed versus chosen exercise/daily physical activity on age differences in LAP, HAN, and LAN affective response during and after bouts of exercise/daily physical activity. In addition, future studies examining the effect of exercise on affect might benefit from incorporating affective terms from the LAN quadrant of the affective circumplex.

To my knowledge, the associations between LAP, HAN, and LAN affect composites and overall physical activity levels have not been previously examined. While we did not observe significant associations between affective composites and MVPA, some of the patterns were in the predicted direction, with greater LAP affect and less LAN affect after daily physical activity corresponding to more MVPA. Hence, future studies should have a larger sample size to further examine this question, both in terms of affective response to acute exercise and daily physical activity.

4.6 Exercise goals, associations with affective response, and overall physical activity levels

To my knowledge, this study is the first to show that the classification of hedonic versus instrumental goals can be applied to exercise goals as well. In line with prior work suggesting that the most commonly endorsed goals are related to health/fitness, both groups showed greater orientation towards instrumental goals relative to hedonic goals. Furthermore, consistent with our hypothesis, the results suggested that older adults had a greater orientation towards instrumental goals relative to hedonic goals compared to younger adults, which was primarily driven by greater endorsement of instrumental goals by older adults. Health benefits of exercise/physical activity may be more salient at that age due to the more rapidly declining physical health of older adults and messaging they receive about the benefits of exercising for their health. However, the exercise goals orientation did not predict overall physical activity levels. When the specific goals of enjoyment and health were examined, for consistency with prior work, none were a significant predictor of MVPA levels. This is in contrast to studies that found the goal of enjoyment predictive of overall physical activity levels (Ednie & Stibor, 2017; Dacey et al., 2008). However, both of these studies had a larger sample size. The effect size of enjoyment predicting MVPA was small and the data showed a pattern in the hypothesized direction (i.e., greater endorsement of the enjoyment goal corresponding to more MVPA), hence, our sample size might have been too small to detect the effects. Furthermore, these studies used a self-reported assessment of overall physical activity levels and stage of change in exercise behavior compared to the objective measure in our study. The differences in measurement and operationalization of physical activity might introduce variability in the findings.

In addition, the association between HAP affective response and MVPA was not significantly stronger with greater orientation towards hedonic goals. However, the patterns were in that

hypothesized direction when examining either exercise goal orientation or only hedonic composite. This finding suggests the possibility that people who place higher value on the goal of enjoying the exercise exhibit a stronger association between HAP affect and overall physical activity levels. For people with greater orientation towards hedonic (i.e., short-term) goals, it might be more important to engage in physical activities that increases HAP affect which, in turn, potentially leads to greater engagement in physical activity. Future work needs to use a larger sample size to thoroughly examine the role of exercise goals, in conjunction with affective responses, in sustained, regular physical activity engagement. Additionally, a future study can examine whether people with greater orientation towards hedonic goals differ in their recall of affective experience of prior physical activity or affective judgments of future engagement in physical activity.

Finally, additional post-hoc analyses examined whether exercise goals predicted the affective response to daily physical activity. For example, perhaps having a greater orientation towards hedonic goals for exercise/physical activity contributes to experiencing more positive and less negative affect in response to daily physical activity. Older adults showed a greater LAP affective response to daily physical activity with greater endorsement of hedonic goals, while younger adults showed a trend towards the opposite pattern. This was a novel finding that has not been examined in prior literature. As previously mentioned, older adults prefer LAP affect (Scheibe et al., 2013), hence, their definition of exercise enjoyment might be daily physical activity that increases LAP affect. Future studies might need to address the differences in the associations between the goal of enjoyment versus the actual experience of enjoyment during daily physical activity on the affective responses in younger and older adults.

4.7 Limitations

There are several limitations to this study that should be mentioned and considered. First, due to convenience and logistical restrictions, our sample of young adults consisted of college students while our sample of older adults was from the community. As mentioned above, the sampling differences might have influenced some of our findings. In addition, there was a lack of information about the broader sociocultural context of the participants, such as socioeconomic status, neighborhood characteristics, and access to exercise/physical activity resources. These factors could have influenced the affective responses to different types of physical activities, as well as the overall physical activity levels, differently in younger and older adults. For example, college students might be more likely to have access to a nearby gym compared to older adults from the community. Another limitation was that each of the affective composites consisted of only three affective terms to keep the EMA survey brief. However, that does likely reduce the reliability of the affective composites. Another potential concern is that I had a smaller sample size based on a priori power calculation but also more broadly than what was needed to detect some of the effects (e.g., exercise goals in relation to MVPA). In addition, although we used actigraphy to obtain an objective measure of overall physical activity levels, it is likely that we missed some daily physical activities, such as physical activities done in the water. Finally, our sample was highly educated and primarily White, hence, the results may not generalize to other populations in the community.

4.8 Future studies

To my knowledge, this is one of the first studies to directly compare affective responses to daily physical activity and their association with overall physical activity levels in both younger and older adults. Future studies should include larger sample sizes and either increased number of

days or number of prompts per day to be able to robustly assess affect after, but also during, daily physical activity. An important future study will examine the affective responses in sedentary younger and older adults since these responses might differ significantly from responses of more active individuals. While we did consider some of the contextual factors impacting affective response to daily physical activity in this study (e.g., social and physical context), future studies can examine additional time-varying moderators, such as current stress, type of physical activity (e.g., weights, running), and sleep quality. In addition, an important future study will examine how the types of physical activities (e.g., walking, weight lifting at the gym, sports, gardening) people engage in vary across adulthood (young vs middle-aged vs older adults). An additional interesting aspect of the study could investigate how the types of physical activities might differ depending on the social context in different age groups. For example, older adults might prefer walking as a physical activity they do alone compared to younger adults who might prefer to lift weights alone. Another line of work might examine whether other factors might moderate the age differences in affective responses to daily physical activity, including emotion regulation skills, BMI, and personality. Finally, future work should focus on examining age differences in affective response to exercise/physical activity in both laboratory and naturalistic settings to allow for examination of age differences in underlying neurobiological mechanisms of the affective response, as well as in daily life.

In summary, daily physical activity was found to be associated with greater high arousal positive affect and less low arousal negative affect to the same extent in both younger and older adults. This is an important finding for the conceptualization of age differences in the model of affective responses to daily physical activity that will allow for further examination of age differences in the underlying neurobiological mechanisms and correspondence to affective response in daily

life. While social context did not show a significant relationship with affective responses, there was some potential indication that greater enjoyment during daily physical activity could be beneficial for the affective responses across the adulthood. Furthermore, enjoyment and engagement in daily physical activity outdoors might be particularly relevant for younger adults to experience more positive affect after daily physical activity. This result can potentially impact recommendations for helping younger and older adults have a positive experience when engaging in daily physical activity. Furthermore, future research needs to consider whether affective responses might differ when considering daily physical activity more broadly versus more specifically acute exercise.

Additionally, affective response was not associated with overall physical activity levels, indicating that a larger sample size is needed, that affect may not be a robust factor in models of physical activity adherence, or that other potential moderators may need to be considered. In terms of exercise goals, this study showed that the distinction between hedonic and instrumental goals can also be applied to exercise goals. Even though older adults showed greater orientation towards instrumental goals than younger adults, this did not mediate the differences in overall physical activity levels, indicating that exercise goals might also be limited as a contributing factor to regular, sustained physical activity engagement. However, while not significant, patterns suggested that people who endorse hedonic goals for exercising to a greater extent show a stronger correspondence between high arousal positive affective response and overall physical activity levels. If future studies with larger sample sizes also detect this effect, this result can facilitate recommendations for increasing physical activity engagement based on what people endorsed as their exercise goals. These results have important implications for the understanding of age differences in exercise goals and affective responses to daily physical activity, as well as

the proposed causal chain of greater affective response leading to greater engagement in physical activity. It is important to examine in the future whether affective responses and exercise goals might play a differing role in models of exercise versus physical activity adherence. Overall, this study provides results that can serve as a first step for future studies that can use a larger sample size and provide a more thorough understanding of the role of affective responses and exercise goals in sustained, regular physical activity engagement in younger and older adults.

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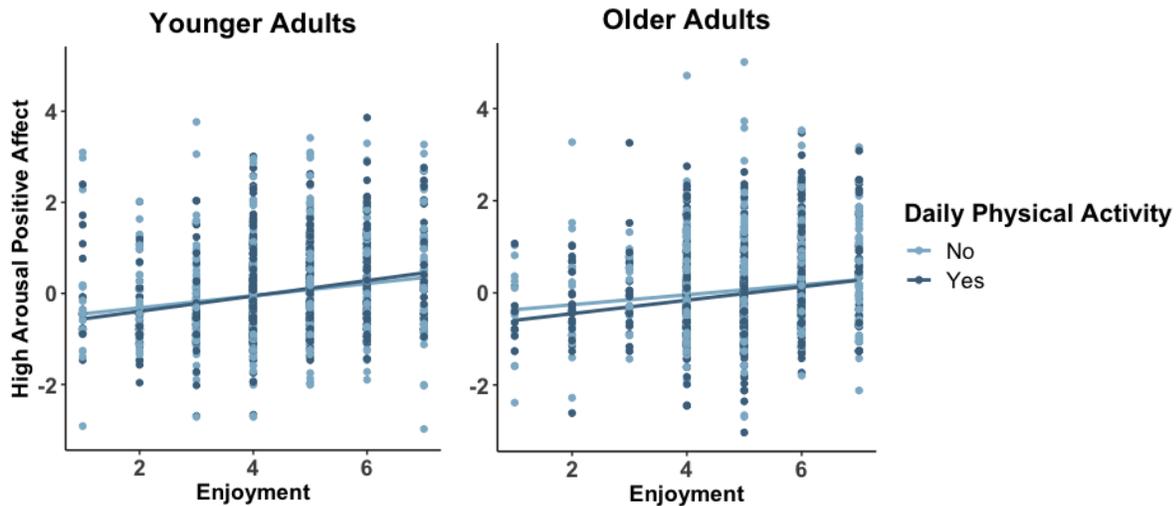
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Appendix A

Planned exploratory models examined whether other factors, including physical context (indoor vs outdoor vs both indoor and outdoor), self-reported physical exertion during the activity, and self-reported enjoyment during the activity, moderated age differences in HAP affective responses to physical activity. In the models of self-reported daily physical activity, only self-reported enjoyment was found to be a significant moderator ($p=0.047$), see Supplementary Tables 1-3. Greater enjoyment was associated more strongly with higher HAP affect after daily physical activity compared to other activities in younger adults ($p=0.001$), while older adults showed similar association between HAP affect and enjoyment regardless of daily physical activity endorsement ($p=0.691$), see Supplementary Figure 1. However, this effect was not observed when daily physical activity was defined via actigraphy, see Supplementary Table 1. In addition, greater HAP affective response after daily physical activity was reported in older adults compared to younger adults ($p=0.019$).



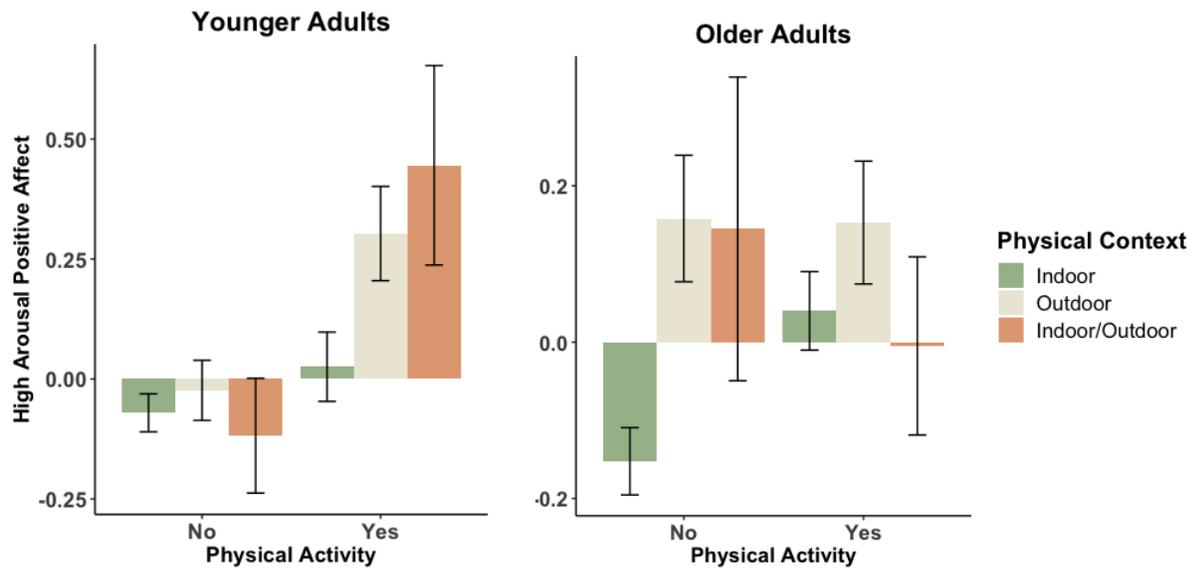
Supplementary Figure 1 HAP affect and enjoyment across prompts with and without physical activity in younger and older adults

Supplementary Table 1 The effect of enjoyment on HAP affective response to prompts with and without daily physical activity

High Arousal Positive Affect						
<i>Predictors</i>	Self-reported model			Actigraphy-defined model		
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>
(Intercept)	-0.49	-0.68 – -0.29	<0.001	-0.69	-0.90 – -0.48	<0.001
Age Group	-0.18	-0.51 – 0.14	0.275	0.16	-0.19 – 0.50	0.376
Enjoyment	0.09	0.05 – 0.14	<0.001	0.15	0.10 – 0.20	<0.001
Daily Physical Activity	-0.38	-0.73 – -0.03	0.032	0.16	-0.25 – 0.56	0.447
Age Group x Enjoyment	0.01	-0.06 – 0.08	0.742	-0.05	-0.12 – 0.02	0.182
Age Group x Daily Physical Activity	0.64	0.10 – 1.18	0.019	-0.33	-0.91 – 0.25	0.266
Daily Physical Activity x Enjoyment	0.13	0.05 – 0.20	0.001	-0.00	-0.09 – 0.08	0.928
Age Group x Enjoyment x Daily Physical Activity	-0.11	-0.22 – -0.00	0.047	0.07	-0.05 – 0.19	0.282

Note: bold = significant at $p < .05$. Self-reported = participants endorsed whether they engaged in daily physical activity; actigraphy-defined = daily physical activity was estimated via actigraphy

When daily physical activity was defined via actigraphy, physical context was found to moderate the age differences in affective response, such that only younger adults reported greater HAP affect when physical activity was done indoors and outdoors relative to only indoors ($p=0.016$, $p=0.033$). The primary age difference seems to be when the activity was done both indoor and outdoor, see Figure 8. Finally, self-reported physical exertion was not a significant moderator in either self-reported or actigraphy-defined daily physical activity.



Supplementary Figure 2 HAP affect across physical context in prompts with and without physical context

Supplementary Table 2 The effect of physical context on HAP affective response to self-reported and actigraphy-defined daily physical activity

High Arousal Positive Affect						
<i>Predictors</i>	Self-reported model			Actigraphy-defined model		
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>
(Intercept)	-0.11	-0.18 – -0.04	0.002	-0.07	-0.15 – 0.02	0.116
Age Group	-0.09	-0.20 – 0.02	0.116	-0.09	-0.21 – 0.04	0.170
Outdoor	0.03	-0.18 – 0.23	0.786	0.05	-0.11 – 0.22	0.517
Indoor/Outdoor	0.26	-0.12 – 0.64	0.175	-0.05	-0.34 – 0.24	0.728
Daily Physical Activity	0.34	0.19 – 0.48	<0.001	0.09	-0.06 – 0.24	0.222
Age Group x Outdoor	0.09	-0.22 – 0.40	0.580	0.27	0.02 – 0.52	0.032
Age Group x Indoor/Outdoor	-0.20	-0.73 – 0.34	0.473	0.35	-0.14 – 0.84	0.165
Age Group x Daily Physical Activity	0.02	-0.18 – 0.22	0.845	0.10	-0.09 – 0.30	0.305
Daily Physical Activity x Outdoor	-0.12	-0.38 – 0.15	0.392	0.24	-0.03 – 0.51	0.076
Daily Physical Activity x Indoor/Outdoor	-0.54	-1.03 – -0.06	0.029	0.47	-0.10 – 1.04	0.106
Age Group x Daily Physical Activity x Outdoor	0.07	-0.31 – 0.46	0.706	-0.45	-0.81 – -0.08	0.016
Age Group x Daily Physical Activity x Indoor/Outdoor	0.45	-0.23 – 1.13	0.198	-0.81	-1.57 – -0.06	0.033

Note: bold = significant at $p < .05$. Self-reported = participants endorsed whether they engaged in daily physical activity; actigraphy-defined = daily physical activity was estimated via actigraphy

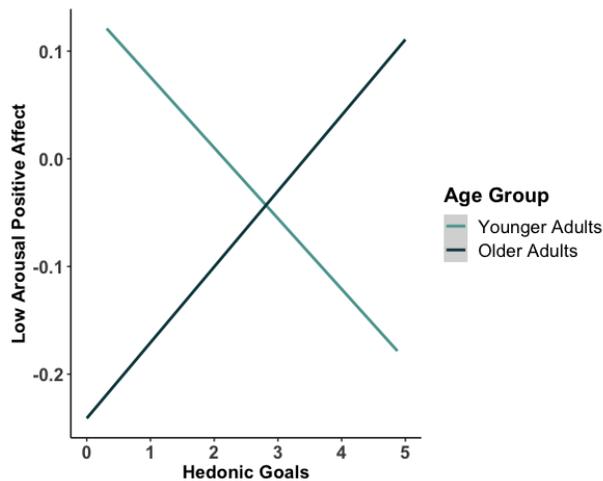
Supplementary Table 3 The effect of physical exertion on HAP affective response to self-reported and actigraphy-defined daily physical activity

High Arousal Positive Affect							
<i>Predictors</i>	Self-reported model			Actigraphy-defined model			
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>	
(Intercept)	-0.22	-0.32 – -0.12	<0.001	-0.33	-0.44 – -0.22	<0.001	
Age Group	-0.01	-0.18 – 0.16	0.924	0.04	-0.14 – 0.21	0.691	
Physical Exertion	0.06	0.02 – 0.10	0.004	0.10	0.07 – 0.13	<0.001	
Daily Physical Activity	0.04	-0.18 – 0.25	0.736	0.29	0.09 – 0.49	0.004	
Age Group x Physical Exertion	-0.04	-0.11 – 0.03	0.274	-0.02	-0.07 – 0.03	0.404	
Age Group x Daily Physical Activity	0.14	-0.20 – 0.47	0.429	-0.26	-0.55 – 0.03	0.081	
Daily Physical Activity x Physical Exertion	0.02	-0.04 – 0.07	0.581	-0.05	-0.10 – 0.01	0.089	
Age Group x Physical Exertion x Daily Physical Activity	0.02	-0.08 – 0.11	0.750	0.06	-0.01 – 0.14	0.111	

Note: bold = significant at $p < .05$. Self-reported = participants endorsed whether they engaged in daily physical activity; actigraphy-defined = daily physical activity was estimated via actigraphy

Appendix B

Post-hoc analyses examined whether exercise goals were associated with affective response to daily physical activity. Each of the affective composites served as the outcome in separate analyses while age group and exercise goal orientation were entered as independent variables and a two-way interaction. In addition, separate models examined hedonic and instrumental composites individually. For LAP affect ($\beta=0.13$, $SE=0.05$, $CI [0.03, 0.24]$, $p=0.013$), greater endorsement of hedonic exercise goals was associated with greater LAP affective response to daily physical activity in older adults ($p=0.018$) but the association did not reach significance in younger adults ($p=0.152$), see Supplementary Figure 3. None of the other models were significant for HAP, HAN, and LAN affect (all p 's > 0.187).



Supplementary Figure 3 Relationship between hedonic goals and LAP affect in younger and older adults

Appendix C

In order to see whether there was an effect of age within the older adult group only, post-hoc analyses were done examining the impact of the continuous age variable on affective responses to daily physical activity. The results should be interpreted with caution due to models being likely underpowered. HAP, LAP, HAN, or LAN affective response to daily physical activity did not differ based on age (all p 's > 0.095). Age among older adults did not predict overall physical activity levels, i.e. MVPA ($\beta=-0.001$, $SE=0.003$, $p=0.639$). Age-invariant HAP affective response to physical activity did not differ across social context (Age x Physical Activity x Social Context (Person): $\beta=0.01$, $SE=0.02$, $p=0.762$), although there was a trend for greater age being associated with less HAP affect when doing the daily physical activity in a group (Age x Physical Activity x Social Context (Group): $\beta=-0.06$, $SE=0.03$, $p=0.053$).

In terms of exercise goals, age among older adults did not predict exercise goal orientation ($\beta=-0.008$, $SE=0.008$, $p=0.316$). However, age did moderate the effect of instrumental goals on LAP affective response ($p=0.021$), with older adults who endorsed less instrumental goals showing less LAP affect after daily physical activity with greater age.

Supplementary Table 4 The effect of age and instrumental goals on LAP affect in older adults only

<i>Predictors</i>	Low Arousal Positive Affect		
	<i>Estimates</i>	<i>CI</i>	<i>p</i>
(Intercept)	4.58	0.56 – 8.60	0.026
Instrumental Goals	-1.27	-2.42 – -0.13	0.030
Age	-0.07	-0.14 – -0.01	0.017
Instrumental Goals x Age	0.02	0.00 – 0.04	0.021