A Mixed-Methods Analysis of Mechanisms Influencing the Association Between Physical Activity, Affect, and Satisfaction with Life in Adolescents' Daily Lives

Matthew Bourke

Bachelor of Applied Science (Human Movement) (Honours)

Institute for Health and Sport, Victoria University, Melbourne, Australia

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Declaration

I, Matthew Bourke, declare that the PhD thesis entitled "A Mixed-Methods Analysis of Mechanisms which may Influence the Association Between Physical Activity, Affect, and Satisfaction with Life in Adolescents' Daily Lives" is no more than 80,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This exegesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work.

I have conducted my research in alignment with the Australian Code for the Responsible Conduct of Research and Victoria University's Higher Degree by Research Policy and Procedures.

Signature: [redacted] Date: 21/10/2021

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Abstract

This thesis examined the within-person and between-person associations between physical activity, affect and satisfaction with life in adolescents' daily lives. Understanding these associations is important because integral affect experienced during physical activity may predict future participation in physical activity behaviours. Additionally, understanding if adolescents who are more active experience more positive incidental affect and satisfaction with life is important to illuminate the benefits of physical activity on wellbeing. Despite growing recognition of the within-person and between-person associations between physical activity, affect, and satisfaction with life, little is known about mechanisms that may moderate or mediate these relationships. Therefore, the overarching aim of this thesis is to investigate the mechanisms that may influence these associations.

A mixed-methods design was used to achieve this aim. Overall, 125 adolescents participated in an ecological momentary assessment (EMA) study. They were asked to report their momentary behaviours, physical environment, social context, and affect on multiple occasions each day for four-days. Additionally, participants were asked to complete a daily diary each evening to report on their daily satisfaction with life and domain specific physical activity. Participants also wore an accelerometer to assess device measured levels of physical activity over the four days. Additionally, 15 participants completed semi-structured interviews to identify factors that lead to experiencing more favourable affect whilst active.

Results from the EMA study showed that participants who engaged in more recreational moderate-to-vigorous physical activity (MVPA) on average than others reported more positive valence, greater energetic arousal, and less tense arousal. Additionally, adolescents reported feeling more energetic, but also more tense when participating in more

recreational MVPA than usual. No domains of MVPA had a within-person association with valence. Considering the social context and physical environment, adolescents reported more positive valence and energetic arousal whilst outdoors than indoors and more energetic arousal when with others than alone, indicating there may be some additional benefits to being physically active in outdoors and with other people. Additionally, results showed that being active was only inversely related to tense arousal when completed outdoors. Results from semi-structured interviews added to these findings and indicated several social (e.g., doing physical activities alone or with others), environmental (e.g., doing physical activities outdoors), and cognitive factors (e.g., finding activities fun and enjoyable) were perceived by participants to influence their affective experience whilst active. Finally results from daily diaries showed that adolescents were more satisfied with their life on days when they accumulated more device-measured overall, light, and moderate-intensity physical activity than usual. There was also an indirect between-person association between leisure-time physical activity and device-measured vigorous intensity physical activity through energetic arousal.

The results from this thesis show that recreational physical activities have the strongest between-person association with subjective wellbeing in adolescents. Physical activity guidelines for mental health that focus on recreational physical activities may be warranted. More research is still needed, however, to fully understand the mechanisms that explain why recreational physical activities are more strongly related to wellbeing. Results also show that the context in which physical activities occur can influence the within-person association with affect. Therefore, it is important to consider the physical environments and social contexts physical activities are participated in when examining the within-person association between physical activity and affect.

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Chapter 1: Introduction

Physical Activity and Health in Adolescents

Physical activity is defined as "any bodily movement produced by skeletal muscles that results in energy expenditure" (Caspersen et al., 1985, p. 126). Adolescence is a unique stage of human development between the ages of 10-19 years (World Health Organisation, 2021). There is extensive evidence linking physical activity with several health indicators in adolescents (Janssen & LeBlanc, 2010; Poitras et al., 2016). Longitudinal studies have shown moderate-to-vigorous physical activity (MVPA) may have a protective effect against adiposity (Janssen et al., 2019; Ramires et al., 2015), and may be an effective strategy to improve body composition in adolescents affected by overweight and obesity (Al-Khudairy et al., 2017; Vasconcellos et al., 2014). MVPA is also associated with several cardio-metabolic biomarkers in adolescents independent of weight status (Ekelund et al., 2012). The amount of time adolescents spend participating in MVPA is inversely associated with systolic blood pressure, triglycerides and insulin, and positively related to high-density lipoprotein cholesterol (Ekelund et al., 2012; Jenkins et al., 2017). Therefore, higher levels of MVPA are associated with a lower risk of metabolic syndrome and insulin resistance in adolescents (Guinhouya et al., 2011; Oliveira & Guedes, 2016). Other physical health benefits of physical activity in adolescents include increased bone strength (Tan et al., 2014) and improved fitness (Poitras et al., 2016).

In addition to the physical health benefits, psychological and cognitive health benefits are associated with engagement in physical activity (Biddle et al., 2019).

Engagement in physical activity may have a protective effect against depression in non-clinical adolescent populations (Brown et al., 2013). Additionally, meta-analytic evidence shows that physical activity has a large treatment effect on depressive symptoms in adolescents with clinical levels of depressive symptoms (Bailey et al., 2018; Carter et al., 2016). Similarly, there is some evidence that shows that regular engagement in physical activity is associated with lower levels of anxiety in adolescents (McMahon et al., 2017), and increased levels of physical activity can reduce symptoms of anxiety (Ahn & Fedewa, 2011; Carter et al., 2021). Although studied less often, there is emerging research which indicates that physical activity may promote subjective wellbeing in adolescents (Costigan et al., 2019; Rodriguez-Ayllon et al., 2019). Research has also found that adolescents' cognitive and executive functioning improves after acute bouts of physical activity (Li et al., 2017; Xue et al., 2019). Moreover, evidence supports a positive relationship between regular MVPA and cognitive functioning and academic performance in adolescents (Booth et al., 2014; Esteban-Cornejo et al., 2015; Poitras et al., 2016).

Adolescent Physical Activity Guidelines and Epidemiology

Given the robust evidence supporting the health benefits of participating in physical activity for adolescents, the Australian Department of Health has developed evidence-based 24-hour movement guidelines for young people aged 5-17 years (Department of Health, 2018). These guidelines recommend that young people accumulate at least 60 minutes of MVPA, involving mainly aerobic activities, on all seven days of the week. The guidelines suggests that young people also accumulate several hours of a variety of light intensity physical activities each day; and vigorous intensity physical activities, as well as those activities that strengthen muscle and bone, should be incorporated at least three days per week. Further, young people should replace sedentary time with MVPA, while preserving sufficient sleep to achieve greater health benefits. These guidelines are consistent with guidelines from other developed nations, including the United States (US Department of Health and Human Services, 2018), Canada (Canadian Society for Exercise Physiology, 2019) and the United Kingdom (Department of Health and Social Care, 2011). More recently, global physical activity guidelines have been updated and suggest that adolescents should accumulate an *average* of at least 60 minutes of MVPA daily, which is slightly different from the previous recommendation of at least 60 minutes every day of the week (Bull et al., 2020).

Inauspiciously, the most recent published results from the Australian Health Survey estimate that only 1.9% of young people aged 15-17 years achieve the Australian 24-hour movement guidelines, and only 10.3% of young people accumulate at least 60-minutes of MVPA on all seven days of the week (Australian Bureau of Statistics, 2019). However, insufficient physical activity during adolescence is not only a public health concern in Australia. It is estimated that fewer than 20% of adolescents accumulate 60 minutes of daily MVPA worldwide (Guthold et al., 2019). The percentage of young people achieving physical activity guidelines is likely lower in developed nations, where adolescents may participate in more screen time and may be required to participate in less manual chores or labour (Aubert et al., 2018). For example, results from a large representative sample of Canadian youth showed that only 7% and 6% of boys and 5% and 2% of girls aged 11-14 and 15-19 years respectively accumulated at least 60 minutes of device measured MVPA on six days of the week

(Colley et al., 2011). In the United States, it is estimated that 7.5% and 5.1% of 12-15 year olds and 16-19 year olds achieve physical activity guidelines, respectively (Katzmarzyk et al., 2016), while in the UK, it is estimated that 12% of adolescents aged 13-15 years old accumulate recommended levels of physical activity (National Health Service, 2018). Research has also consistently shown that levels of physical activity drop significantly from childhood to adolescence (Corder et al., 2015; Dumith et al., 2011; Farooq et al., 2020; Farooq et al., 2018), and continue to drop during adolescence (Corder et al., 2019). As such, increasing engagement in physical activity in adolescents has been identified as a priority in the World Health Organization’s Global Action Plan on Physical Activity (World Health Organization, 2018). The action plan sets out a global target of a relative reduction in the prevalence of adolescents not accumulating sufficient levels of physical activity by 15% by 2030.

Social Cognitive Theories and Physical Activity

The most prominent theoretical approaches to understand determinants of physical activity behaviours have fallen within the social-cognitive archetype (Davis et al., 2015; Rhodes et al., 2019). Prominent models include the Social-Cognitive Theory (Bandura, 1986), the Theory of Reasoned Action/Planned Behaviour (Ajzen, 1985), and the Transtheoretical Model of Behaviour Change (Prochaska & Velicer, 1997). These models are centered on the premise that people make conscious plans or intentions to participate in behaviours based on psychological and social factors and that they can self-regulate their behaviours to realise these plans or intentions. Factors these models postulate as determinants of people’s behaviours include their beliefs about their ability to perform a given behaviour (e.g. self-efficacy, perceived behavioural control), their perceptions about positive and negative outcomes associated with participating in a behaviour (e.g. behavioural beliefs, perceived outcome expectations), and sociocultural facilitators and barriers (e.g. social norms, social support). These factors are theorised to predispose, enable and reinforce adolescents' participation in physical activity (Welk, 1999).

Undoubtedly, there is strong empirical evidence to support relationships between social-cognitive factors and physical activity in adolescents. For example, psychological factors including perceived behavioural control, self-efficacy, motivation and goal setting/planning have consistently been found to be positively associated with participation in physical activity in adolescents (Cortis et al., 2017). Longitudinal studies also show that self-efficacy and perceived behavioural control are determinants of adolescents' physical activity changes over time (Craggs et al., 2011; Dishman et al., 2019). Social constructs including parental and friend support for physical activity also have consistent positive cross-sectional and longitudinal associations with physical activity in adolescents (Biddle et al., 2011; Craggs et al., 2011; Fitzgerald et al., 2012). Despite this, results from a meta-analysis suggested that social cognitive constructs explain only 33% of the variance in physical activity in adolescents (Plotnikoff et al., 2013).

Given the modest association between social cognitive constructs and physical activity, the predictive capabilities of social-cognitive models have warranted critical appraisal. One critique of the Social-Cognitive Theory is that the construct of self-efficacy indicates *whether* people are motivated to be physically active but not *why* they are motivated (Williams & Rhodes, 2016). Furthermore, researchers suggest that outcome expectations may causally influence physical activity self-efficacy, and therefore may better explain why someone is motivated to be physically active than perceived self-efficacy (Beauchamp et al., 2019; Williams, 2010). This is in opposition to the tenets Social-Cognitive Theory, which posits that self-efficacy temporally precede outcome expectations, and that this relationship is not bidirectional (Beauchamp et al., 2019; Williams, 2010) This contradiction has led to self-efficacy receiving undue prominence in examination of human behaviour at the expense of outcome expectations (Williams, 2010).

Considering the Theory of Planned Behaviour, a major criticism is its failure to explain intention-behaviour dissonance (Sniehotta et al., 2014). Intention-behaviour dissonance is when an individual fails to act on intentions to perform a behaviour, termed “inclined abstainers” (Orbell & Sheeran, 1998). In one review, it was estimated that 48% of adults who intended to be physically active were inclined abstainers (Rhodes & de Bruijn, 2013a). Intention-behaviour dissonance is likely similar or even greater in young people who may have lower volitional control over physical activity behaviours than adults (Downs & Hausenblas, 2005). Therefore, it is essential to understand the factors that may explain why adolescents do not follow through on intentions to be physically active (Rhodes & Dickau, 2012).

Given the limited predictive capabilities of social cognitive constructs in explaining adolescents’ participation in physical activity, complementary approaches to understanding their physical activity behaviours are necessary. One complementary approach, for which research has burgeoned, is the relationship between affect and physical activity (Ekkekakis et al., 2013).

Defining Affect

Affect is conceptualised in multiple ways, including core affect, moods and emotions. Core affect is defined as “the most elementary consciously accessible affective feelings…that need not be directed at anything” (Russell & Barrett, 1999, p. 806). It is theorised to consist of two orthogonal and bipolar dimensions of valence (i.e., pleasure – displeasure) and activation (i.e., activation – deactivation) on a circumplex model (Russell, 1980). Although the circumplex model of affect suggests core affect is measured along two axes, research has demonstrated that there may be two basic dimensions of arousal, namely, energetic arousal (measured from energetic to tired) and tense arousal (measured from tense to calm), and these dimensions are not simply mixtures of valence and activation (Schimmack & Rainer, 2002). Therefore, representing a combination of the circumplex model and Thayer’s two-dimensional model of arousal (Thayer, 1989), it has been suggested that a three-dimensional structure of affect, including valence, energetic arousal and tense arousal most accurately describes affect experienced by young people (Figure 1.1) (Leonhardt et al., 2016).

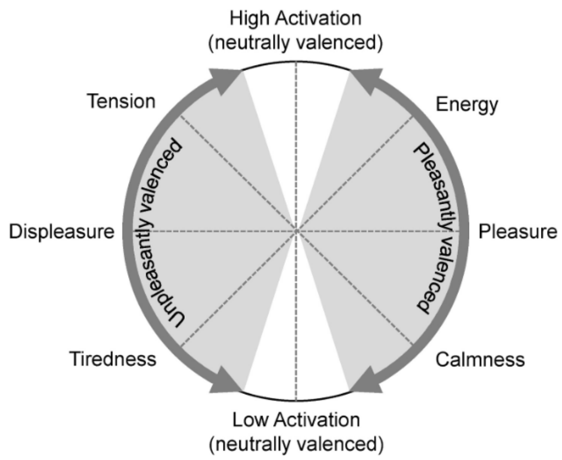

Figure 1.1 Illustration of the three-dimensional model of affect including the dimension of valence (i.e., displeasure - pleasure), energetic arousal (i.e., tiredness, energy), and tense arousal (i.e., tension - calmness). Reprinted from “Do you find exercise pleasant or unpleasant? The Affective Exercise Experiences (AFFEXX) questionnaire”, by P. Ekkekakis, Z. Zenko and S. Vazou, 2021, Psychology of Sport and Exercise, 55(1), p. 3. Copyright 2021 by Elsevier B.V.

Based on a 45-degree rotation of the circumplex model, core affect can also be conceptualised as positive affect (also referred to as positive activation) and negative affect (also referred to as negative activation) (Watson & Tellegen, 1985). Positive affect is theorised to consist of positive valence high activation states (e.g. interested, excited), and negative affect consists of negative valence high activation states (e.g., distressed, upset). Therefore, the authors of the rotated model argue that positive and negative affect are “*descriptively bipolar* but *affectively unipolar* dimensions” (Zevon & Tellegen, 1982, p. 112, emphasis in original), arguing that only the high end of each dimension indicates the presence of affect, whereas the low end of each dimension indicates the absence of affect (Watson & Tellegen, 1985; Zevon & Tellegen, 1982). Notably, the high activation poles of energetic arousal and tense arousal fall in similar places on the affect circumplex to positive affect and negative affect, respectively (Yik et al., 1999).

In addition to core affect, affect may also be conceptualised as emotions and moods. Whereas core affect may be unattributable, moods and emotions result from interrelated sub-events concerned with a particular phenomenon, including cognitive appraisals of the phenomenon, changes in core affect, and physiological adaptations (Kleinginna & Kleinginna, 1981). Additionally, moods and emotions may lead to expressive and adaptive changes in behaviours (Kleinginna & Kleinginna, 1981). The distinction between emotions and moods is less clear but can be considered in terms of intensity and length (Ekkekakis, 2013). Emotions are more intense and transient, whereas moods are less intense but last longer (Ekkekakis, 2013). Although these are distinct conceptualisations of affect, they are not incompatible. Instead, they represent the hierarchical structure of core affect, moods and emotions (Figure 1.2). Core affect represents higher-order dimensions that account for overlapping commonalities between lower order discrete moods and emotions (Ekkekakis & Petruzzello, 2000; Watson & Clark, 1997).

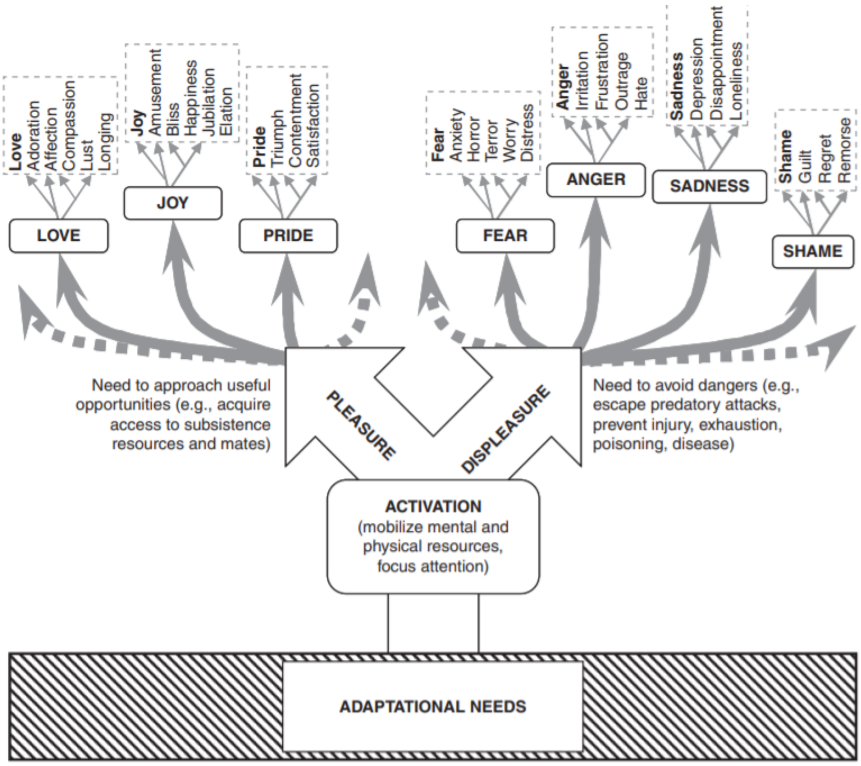

Figure 1.2 Hierarchical structure of affect. Reprinted from "The measurement of affect, mood, and emotion: a guide for health-behavioral research" (p. 70), by P. Ekkekakis, Cambridge, UK: Cambridge University Press. Copyright 2013 by Panteleimon Ekkekakis.

In addition to the different conceptualisations of affect in terms of core affects, moods and emotions, affect can be further conceptualised as integral or incidental (Stevens et al., 2020; Williams & Evans, 2014; Williams et al., 2019). Incidental affect is defined as "affect that is not experienced in the context of a behaviour but may nonetheless … be influenced by the behaviour" (Williams et al., 2019; p. 1269). Alternatively, integral affect, or the affective response to a behaviour, is the immediate consequence of participating in a behaviour (Stevens et al., 2020; Williams & Evans, 2014; Williams et al., 2019). Regarding participation in physical activity, integral affect is the affect someone experiences during physical activity or immediately after participating in physical activity. In contrast, incidental affect may be conceptualised as the association between usual levels of physical activity and affect (Williams et al., 2019).

Affect As a Determinant of Physical Activity

Dual-process models postulate that behavioural choices result from an interplay between two functionally distinct processes (Ekkekakis, 2017). These are Type 1 processes, which are hypothesised to be an automatic, non-conscious process, and Type 2 processes, which are hypothesised to be a reflective, conscious process (Figure 1.3) (Ekkekakis, 2017). Consistent with dual-process models, it is suggested that affect is processed in both automatic and reflective ways (Stevens et al., 2020; Williams, 2019; Williams & Evans, 2014; Williams et al., 2019). Reflective processes of affect include concepts such as anticipated affect and affective attitudes towards participation in physical activity (Williams et al., 2019), which, although about affect, are based on extensive cognitive processes (Ekkekakis et al., 2018). Despite being cognitively processed, it is important to note that affective attitudes differ from other cognitively processed attitudes towards physical activity, such as the beliefs of the effects of a behaviour on one's health (Williams et al., 2019). As such, the importance of differentiating between cognitive and affective beliefs, attitudes and expectations towards physical activity behaviours in traditional social-cognitive models is now recognised (Gellert et al., 2012; Rhodes et al., 2006). Reflectively processed affect is hypothesised to influence physical activity intentions and goals (Stevens et al., 2020; Williams & Evans, 2014; Williams et al., 2019) and explain physical activity intention behaviour dissonance (Rhodes & de Bruijn, 2013b; Rhodes & Yao, 2015). Empirical research has shown that reflectively processed affect has a moderate positive effect on adolescents' levels of physical activity (Nasuti & Rhodes, 2013).

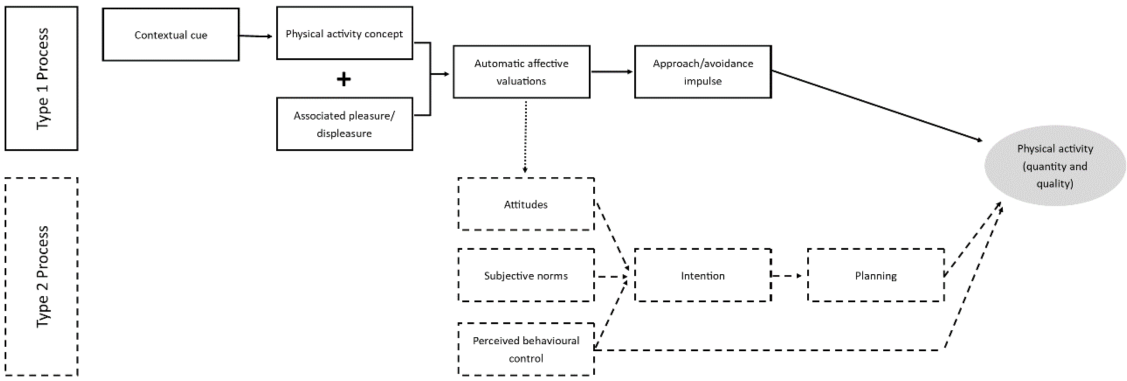

Figure 1.3 Conceptual dual-process model of physical activity with the Theory of Planned behaviour as an example. Solid lines represented Type 1 processes and dotted lines represent Type 2 processes. Adapted from "Automatic affective evaluations of physical activity", by D. E. Conroy and T.R. Berry, 2017, Exercise and Sport Sciences Reviews, 45(4), p.232. Copyright 2017 by American College of Sports Medicine.

In addition to reflective processed affect, automatic affective valuations and implicit attitudes of physical activity may also influence whether an individual participates in physical activities (Brand & Ekkekakis, 2018; Conroy & Berry, 2017; Stevens et al., 2020; Williams & Evans, 2014; Williams et al., 2019). Automatic affective valuations and implicit attitudes towards physical activity are noncognitive evaluations of the pleasantness or unpleasantness of participating in physical activity (Brand & Ekkekakis, 2018; Ekkekakis & Brand, 2019). These affective valuations are triggered automatically by behavioural cues (e.g. seeing a pair of running shoes) or the thought of physical activity (Brand & Ekkekakis, 2018; Conroy & Berry, 2017; Ekkekakis & Brand, 2019), and are an antecedent of hedonic motivation, which is a feeling of desire or dread associated with a behaviour (Williams, 2018; Williams, 2019). Empirical evidence has shown that implicit attitudes have a small but significant association with physical activity (Chevance et al., 2019). In addition to having a direct effect on participation in physical activity, automatic processes such as implicit attitudes may inform reflective processes (Brand & Ekkekakis, 2018) and thwart or augment behavioural intentions derived from reflective processes (Rhodes & Gray, 2018).

Although the processes underlying the automatic and reflective affective predictors of physical activity differ (Hyde et al., 2010), it is likely that they are both influenced by lived experiences and learned associations based on affect repeatedly experienced during physical activity (Brand & Ekkekakis, 2018; Conroy & Berry, 2017; Ekkekakis & Brand, 2019; Rhodes & Kates, 2015; Stevens et al., 2020; Sudeck et al., 2016; Williams & Evans, 2014). Therefore, experiencing more favourable affect while physically active is likely associated with more favourable implicit and explicit affective attitudes towards participation in physical activity. Consequently, people may be more likely to participate in physical activities if they experience more favourable affect while physically active (Bryan et al., 2007; Ekkekakis & Dafermos, 2012; Williams, 2008). Empirical evidence has consistently shown a positive relationship between affect experienced during physical activity and future physical activity behaviours (Rhodes & Kates, 2015). For example, Schneider et al. (2009) found that adolescents who had a positive change in valence during a bout of moderate-intensity physical activity accumulated an average of 54.25 minutes of device measured MVPA per day. In contrast, those who had a neutral and negative change in valence during a bout of moderate-intensity physical activity accumulated 46.96 and 39.83 daily minutes of device measured MVPA, respectively. Given that affect experienced during physical activity is an antecedent of reflectively processed affect, automatic affective valuations, and consequently physical activity behaviours, it is important to understand the acute association between physical activity and integral affect in adolescents.

Subjective Wellbeing

In addition to understanding the acute association between physical activity and integral affect, it is important to consider how participation in physical activity over longer periods, such as over a day or regular levels of physical activity, is associated with wellbeing in adolescents. Worldwide, it is estimated that 13.4% of children and adolescents are affected by some form of mental health condition (Polanczyk et al., 2015), and mental health disorders account for the greatest burden of disease in young people from high-income countries (Gore et al., 2011). An increasing body of evidence suggests that physical activity is effective in preventing and treating mental illnesses in young people (Biddle et al., 2019); however comparatively fewer studies have studied the potential of physical activity to promote positive mental health (Rodriguez-Ayllon et al., 2019). This is despite the positive psychology movement emphasising the aetiology and promotion of mental health in addition to treating mental illnesses (Seligman & Csikszentmihalyi, 2000).

The World Health Organization (2013) defines mental health as a state of wellbeing and not merely the absence of disease. Central to wellbeing is the concept of subjective wellbeing, which is a term used to describe how an individual feels about their life. Someone's subjective wellbeing is made up of two key components (Diener, 1984; Diener et al., 1985). One of these components is an individual's cognitive judgement of their satisfaction with life based on a comparison with their individual standards based on criteria important to them (Diener, 1984; Diener et al., 1985). The second component of subjective wellbeing is an individual’s underlying affective state (Diener, 1984; Diener et al., 1985). Subjective wellbeing moves beyond social indicators of wellbeing such as economic prosperity and recognises the importance of subjective judgments in evaluating life (Diener et al., 1999). As opposed to social indicators of wellbeing, subjective wellbeing gives credence to experiences that are important to individuals (Diener & Suh, 1997).

Research shows that people generally experience moderately positive levels of subjective wellbeing (Cummins, 1995), and maintaining positive levels of subjective wellbeing is necessary for humans to perform adaptive behaviours (Diener & Diener, 1996). Beyond being necessary for human functioning, subjective wellbeing is associated with psychological and social wellbeing (Gallagher et al., 2009; Proctor et al., 2009). For example, adolescents with very high levels of satisfaction with life score higher on social, intrapersonal and cognitive functioning indicators and lower on indicators of emotional and behavioural problems than those with lower levels of life satisfaction (Suldo & Huebner, 2006). Additionally, adolescents with greater satisfaction with life score higher on several academic indicators corresponding with psychological wellbeing, including school satisfaction, attitude towards education, academic aspirations and academic achievement (Proctor et al., 2010). Life satisfaction may also predict an adolescent’s cognitive engagement at school (Lewis et al., 2011), and changes in an adolescent’s grade point average over time (Ng et al., 2015; Suldo et al., 2011).

Further, satisfaction with life is associated with several indicators of social wellbeing. For example, satisfaction with life is related to more positive interpersonal relationships with parents and peers, less interpersonal stress, and greater social acceptance (Gilman & Huebner, 2006; Proctor et al., 2010). Satisfaction with life is also positively related to intrapersonal indicators of wellbeing, including life meaning, aspirations, self-esteem, happiness and coping, and negatively related to symptoms of depression and anxiety (Gilman & Huebner, 2006; Jiang et al., 2019; Proctor et al., 2010).

Similar to satisfaction with life, there are many benefits of frequently experiencing positive affect (Lyubomirsky et al., 2005). Frequently experiencing positive affect is related with a positive construal of oneself and others, prosocial behaviours and popularity; it precedes fulfilling and productive work and satisfying relationships; and it can lead to increases in sociability, altruism, liking one self and others, effective conflict resolution and original thinking (Lyubomirsky et al., 2005). Additionally, positive affect in adolescents is a significant predictor of several benefits in adulthood, including increased perceived self-worth, increased job competence and satisfaction, greater attachment with close friends, less conflict with romantic partners, and fewer internalising behaviours (Kansky et al., 2016). Therefore, promoting subjective wellbeing may lead to an improvement in young people's functioning and overall wellbeing.

Traditionally, it was believed that people have a subjective wellbeing equilibrium and that an individual's wellbeing does not deviate far from that level (Cummins, 1995). However, research has consistently shown that, although most adolescents experience moderate-to-high levels of subjective wellbeing, ratings of subjective wellbeing decline significantly during adolescence (Goldbeck et al., 2007; González-Carrasco et al., 2017; Tomyn & Cummins, 2011b). Conversely, incidences of common mental health disorders, including depression and anxiety, become more prevalent during adolescence (Merikangas et al., 2010; Whiteford et al., 2013). Therefore, it appears that a restructuring of an individual's subjective wellbeing equilibrium may occur during adolescence. This may be because adolescence is when the human brain must implement multiple complex behaviours during the transition from childhood into adulthood (Paus, 2005). At the same time, important neurobiological developments occur during adolescence, which may contribute to greater emotional reactivity and risk-taking behaviours (Casey et al., 2008), and low self-regulatory competence (Steinberg, 2004), which leave adolescents vulnerable to common psychiatric disorders (Paus et al., 2008). However, changes in the adolescent brain are generally beneficial and prepare adolescents for challenges that lay ahead, except when changes in the adolescent brain are suboptimal in timing or magnitude (Paus et al., 2008). Therefore, in terms of cognitive and affective development, adolescence is a time fraught with both risks and opportunities (Paus et al., 2008; Steinberg, 2005). Consequently, it is crucial to consider factors that can promote subjective wellbeing during adolescence and protect against a decline in wellbeing.

It has been proposed that subjective wellbeing is a function of an individual's personality and events that occur in their life (Headey & Wearing, 1989). Personality is highly stable over time. As such, it does not predict changes in subjective wellbeing; however, events that contrast with an individual's subjective wellbeing equilibrium can produce changes in their subjective wellbeing (Headey & Wearing, 1989). Research has shown that positive and negative daily events are related to young people's subjective wellbeing (Ash & Huebner, 2001; McCullough et al., 2000; Nezlek, 2005; Suldo & Huebner, 2004). Further, daily events (e.g. talking with friends) explains a greater proportion of the variance in subjective wellbeing in adolescents than major life events (e.g. the death of a family member) (McCullough et al., 2000). Given that subjective wellbeing is influenced by daily events, it is possible that physical activity in daily life, and whether it is a positive or negative experience, could impact adolescents' perceptions of subjective wellbeing. Therefore, it is important to understand the association between participation in physical activity and subjective wellbeing in adolescents.

Methods For Examining the Associations Between Physical Activity, Affect and Satisfaction with Life

Traditionally, cross-sectional, longitudinal, and pre-post methods have been used to examine physical activity behaviours, predictors and outcomes (Dunton, 2017). Although these methods provide an understanding of factors that may encourage engagement in, and benefits of, participating in physical activity, they also have some important limitations. Specifically, traditional methodologies measure behaviours infrequently and examine the relationships at a trait level (Dunton, 2017). Therefore, it is impossible to examine within-person, or state level associations using traditional methodologies (Kanning et al., 2013). That is, it is not possible to determine temporally synchronistic intra-individual covariance between two variables using traditional methodologies (Dunton, 2017). The implications of this are clear when considering how the between-person (trait level) and within-person (state level) associations between two variables can differ in magnitude and direction. Take blood pressure, for example. There is a negative between-person association between physical activity and blood pressure, such that those who are more physically active on average than others have lower blood pressure, however, there is a positive within-person association between physical activity and blood pressure, such that people have higher blood pressure than they usually do when they are more physically active than usual (Reichert et al., 2020).

Using methods that can only examine between-person associations is a fundamental limitation when researching the relationship between physical activity, affect and satisfaction in life which are all dynamic and frequently fluctuate over time (Dunton, 2017; Jayawickreme et al., 2017b; Trull et al., 2015). Considering affect, researchers may examine the dynamic relationship between physical activity and affect by asking participants to retrospectively report how they felt during an acute bout of physical activity. However, affective feelings are fleeting, and once they are gone, they can no longer be introspected (Schwarz, 2012). Therefore, when asked to report how they usually feel during a bout of physical activity, an individual's response will be based on semantic knowledge, which may be distorted by memory heuristics bias, and therefore may differ considerably from feelings that were actually experienced (Robinson & Clore, 2002; Trull & Ebner-Priemer, 2013). Additionally, participants' perceptions of the physical activity behaviour and context may be impacted by recall bias when asked to report on past behaviours (Schwarz, 2012). Considering satisfaction with life, using traditional cross-sectional and longitudinal methods only allows researchers to examine the relationship between physical activity and trait satisfaction with life (i.e. one's general appraisals of their life), not state satisfaction with life (i.e. in the moment appraisals of one's life) (Jayawickreme et al., 2017b). Therefore, traditional research methodologies may not effectively describe the effects of daily situational forces on satisfaction with life (Jayawickreme et al., 2017b).

Experimental research overcomes these limitations; however, it too has some other important limitations. Specifically, experimental research is often completed in laboratory settings, and experiments are purposefully conducted in controlled settings to examine specific mechanisms in isolation (Reis, 2012). Therefore, experimental research cannot be considered as ecologically valid, as it cannot ascertain context-specific associations that only occur in real-world settings (Reis, 2012). To overcome these limitations, researchers can use ambulatory assessment methods, which can be used to record real-world experiences as they occur in real-time (Reis, 2012). A prominent ambulatory assessment method for examining behaviours in daily life is ecological momentary assessment (EMA) (Shiffman et al., 2008). EMA involves collecting data in real world settings as participants go about their daily lives. Therefore, EMA can be used to collect data about participants' current states, contexts and behaviours, and participants can complete multiple assessments over relatively short periods (Shiffman et al., 2008). Consequently, EMA cannot only be used to examine the acute relationship between physical activity and affect in daily life, it can also be used to capture information about the contexts in which the relationship occurs and examine spatially synchronous relationships (Dunton, 2017). Therefore, EMA can determine ecological valid associations between physical activity and affective states in daily life.

In addition to EMA studies which may examine the association between physical activity and affect over short timeframes (e.g. 15-30 minutes), researchers may examine the within-person association between physical activity and wellbeing over longer time frames using daily diaries which only prompt participants on a single occasion each day (e.g. in the evening) (Reichert et al., 2020). Therefore, daily diaries may be used to examine how physical activity is associated with daily appraisals of state satisfaction with life.

In addition to the benefits of using EMA and daily diaries to study within-person associations, EMA and daily diaries may also have benefits when examining between-person associations. Using these methods allows researchers to thoroughly describe the lived experiences of adolescents, such as their experiences of affect throughout the day, or how satisfied they are with their life each day over a week, and therefore provides a more detailed overview than cross-sectional studies that involve only a single assessment (Russell & Gajos, 2020; Shiffman et al., 2008). Additionally, with regards to affect, because participants are prompted about their present states, profiles based on multiple EMA prompts provides an assessment of affect as it was experienced as opposed to how it was remembered (Russell & Gajos, 2020). Therefore, multiple EMA or daily diary responses can be used to develop accurate profiles of adolescents that are not impacted by recall bias (Shiffman et al., 2008).

Originally, EMA and diary studies collected data using paper-and-pencil procedures whereby participants completed a diary about the behaviours they engaged in at predetermined intervals throughout the day (e.g. every 15-minutes) (Gorely et al., 2007). With advances in technology, ambulatory assessment is now conducted using mobile electronic devices. There are many advantages of using mobile electronic devices to conduct ambulatory assessment studies, including increased usability, greater ability to randomise and track prompts, and greater compliance than paper-and-pencil methods (Dubad et al., 2017; Heron et al., 2017). Furthermore, as mobile technology becomes more advanced and its use more ubiquitous in society, EMA has become a more feasible and acceptable methodology to collect data about people’s activities, contexts, and feelings (Dubad et al., 2017; Heron et al., 2017). Additionally, EMA can be coupled with the use of wearable sensors, such as accelerometers, to objectively capture an individual's behaviours (Reichert et al., 2020).

Highlighting the efficacy of using EMA for data collection, a recent meta-analysis examining compliance rates in EMA studies conducted with young people found that non-clinical samples of children and adolescents completed an average of 79.15% of EMA prompts (Wen et al., 2017). Physical activity studies utilising EMA have reported similarly high levels of compliance (Liao et al., 2016), and EMA is a valid methodology for examining the contexts in which young people's physical activity occurs (Brannon et al., 2016; Dunton et al., 2012a). Therefore, EMA is a feasible and valid methodology to examine the temporally and spatially synchronous relationships between physical activity and affect in adolescents' daily lives.

In addition to using daily life methods to understand the association between physical activity and affect, researchers may use a mixed-methods design whereby series of techniques are employed to gather and analyse both quantitative and qualitative data to answer linked research questions (McGannon & Schweinbenz, 2011). Employing qualitative methods in addition to qualitative methods may further elucidate factors influencing the relationship between physical activity and affect (e.g., Rose & Parfitt, 2007; Rose & Parfitt, 2010; Stych & Parfitt, 2011). Using a mixed-method approach that combines quantitative and qualitative enquiry has many advantages (Creswell & Planco Clark, 2011). One of the advantages is that mixed methods research results from one method can complement the results from another method and help explain the findings further (Greene et al., 1989). Therefore, using an explanatory sequential research design, researchers can follow-up the quantitative phase of data collection and analysis with qualitative enquiry to explain the quantitative results

(Creswell & Planco Clark, 2011). Results from each of these methods, which provide different forms of evidence into the phenomenon, are reconciled and discussed together to give a more thorough insight into factors that influence the relationship between physical activity and affect (Ryba et al., 2020).

Summary

There is robust evidence of the health benefits of participating in physical activity in adolescents. However, the traditional theoretical perspective to examine predictors of physical activity has only had modest success in explaining why adolescents are physically active. Therefore, there is growing interest in other factors that may be associated with participation in MVPA. One factor that has garnered increased attention is affect. Specifically, integral affect experienced during MVPA may predict future participation in physical activity. Therefore, it is important to understand the acute association between participation in MVPA and affect, and the factors that may influence this relationship.

In addition to integral affect, it is important to consider the association between MVPA and incidental affect and satisfaction with life. This will elucidate whether participating in MVPA promotes wellbeing in adolescents. Using EMA and daily diaries allows researchers to simultaneously examine the within-person and between-person association between MVPA, affect, and satisfaction with life in daily life.

Chapter 2: Literature Review

Content included in this chapter has been adapted from the articles listed below. The original articles can be seen in Appendix A.

Bourke, M., Hilland, T. A., & Craike, M. (2021). A systematic review of the within-person association between physical activity and affect in children's and adolescents' daily lives. *Psychology of Sport and Exercise, 52.* 101825. https://doi.org/10.1016/j.psychsport.2020.101825

Bourke, M., Hilland, T. A., & Craike, M. (2020). Variance in the valenced response during moderate-to-vigorous physical activity: a review of cognitive and contextual mechanisms. *International Review of Sport and Exercise Psychology*. https://doi.org/10.1080/1750984X.2020.1780626

The Acute Within-Person Relationship Between Physical Activity and Affect in Adolescents

Several studies have examined the acute within-person relationship between physical activity and affect in adolescents. Results from experimental studies have shown that adolescents' feelings of valence may remain stable during self-paced and low-intensity physical activities (Schneider & Schmalbach, 2015; Sheppard & Parfitt, 2008b; Stych & Parfitt, 2011), but become more negative during MVPA (Benjamin et al., 2012; Hamlyn-Williams et al., 2014; Malik et al., 2018, 2019; Schneider et al., 2009; Schneider & Graham, 2009; Sheppard & Parfitt, 2008b; Stych & Parfitt, 2011). Other experimental research which has examined differences in valence during sedentary time and physical activity found that older children reported significantly more positive valence during sedentary time than during low, moderate and high-intensity bouts of physical activity (Nagy et al., 2017). In contrast to the findings regarding valence, results from experimental research has shown that feelings of energetic arousal increase in adolescents during acute bouts of MVPA (Benjamin et al., 2012; Malik et al., 2018, 2019; Sheppard & Parfitt, 2008a), while feelings of tense arousal may remain stable (Schneider & Graham, 2009; Subramaniapillai et al., 2016).

In addition to experimental research, several studies have examined the acute within-person association between physical activity and affect in daily life using EMA. However, most of this research has examined positive and negative affect from the rotated circumplex model (Watson & Tellegen, 1985), rather than the dimensions of valence and arousal. Multiple studies have found that levels of MVPA in the 30 minutes before an EMA prompt had a significant positive within-person association with positive affect in children and adolescents (Cushing et al., 2017; Dunton et al., 2014; Smith, Haedt-Matt, et al., 2020; Wen et al., 2018). Another study found a positive within-person association between overall levels of physical activity in the 30 minutes before a prompt and subsequent positive affect in a sample of female adolescents affected and not affected by anorexia nervosa (Kolar et al., 2020). Additionally, a study found adolescents were significantly happier when they reported participating in physical activities than non-physical activities in daily life (Rusby et al., 2014). Studies have also examined the association between physical activities over longer periods before a prompt and subsequent positive affect. One study found that levels of MVPA in the 60 minutes and 120 minutes before an EMA prompt had a positive within-person association with positive affect in a sample of youth with overweight and obesity (Smith, Haedt-Matt, et al., 2020). However, other studies found no within-person association between levels of MVPA in the 60-minutes before an EMA prompt and subsequent positive affect in children (Wen et al., 2018), or happiness in adolescents (Smith, Mason, et al., 2020).

Although there is support for a significant acute within-person relationship between physical activity and subsequent positive affect, there is less support for a within-person association between physical activity and subsequent negative affect in adolescents. Several EMA studies have found a non-significant relationship between levels of MVPA in the 30, 60, and 120 minutes before an EMA prompt and subsequent negative affect (Cushing et al., 2017; Dunton et al., 2014; Smith, Haedt-Matt, et al., 2020; Smith, Mason, et al., 2020; Wen et al., 2018). Additionally, a single study examined the association between total physical activity in the 30 minutes before a prompt and subsequent negative affect in a sample of female adolescents affected and not affected by anorexia nervosa (Kolar et al., 2020). Results indicate that there was not a statistically significant main effect of physical activity on negative affect. However, a statistically significant moderating effect indicated that physical activity was negatively associated with negative affect in participants affected by anorexia nervosa but not participants who were not affected by anorexia nervosa. Another study found that although there was no main effect of total physical activity in the 60 minutes before an EMA prompt on negative affect, there was a significant interaction effect with BMI (Smith, Mason, et al., 2020). Researchers found an inverse within-person association between overall physical activity and negative affect in adolescents with a high BMI, but not those with a low BMI. In addition to studies that have examined the association between physical activity and negative affect, a single EMA study found non-significant within-person relationships between MVPA in the 30 minutes before a prompt and subsequent ratings of depressed mood, anxiety and anger (Cushing et al., 2018).

Considering the concepts from the three-dimensional model of affect (Leonhardt et al., 2016), one study found that the levels of incidental physical activity (i.e. excluding exercise and sport) in windows from 15-to-75 minutes before an EMA prompt had a positive within-person association with valence in a sample of adolescents (Koch et al., 2020). Similarly, levels of incidental physical activity in windows ranging from 15-to-60-minutes before an EMA prompt had a positive within-person association with energetic arousal (Koch et al., 2020). Another two EMA studies found a significant positive within-person association between MVPA in the 30 minutes before a prompt and subsequent energy (Cushing et al., 2017; Dunton et al., 2014). Additionally, researchers found that the levels of incidental physical activity in the 30 minutes before a prompt had a positive within-person association with tense arousal in adolescents, such that adolescents felt tenser when they were more active than usual (Koch et al., 2020).

In summary, there is consistent evidence from EMA studies of an acute within-person association between MVPA and positive affect and energetic arousal. However, results from previous studies indicate that there may not be an acute within-person association between MVPA and negative affect and research on valence and tense arousal is scarce. Although these studies provide some evidence of an acute within-person association between physical activity and subsequent affect in adolescents' daily lives, little is known about what factors may moderate the acute relationship between physical activity and affect (Emerson & Williams, 2015; Liao et al., 2015). Given that affect experienced during physical activity is a potential determinant of future participation in physical activity (Rhodes & Kates, 2015), it is essential to understand under what conditions physical activity has the most favourable association with affect in adolescents' daily lives.

Theories Explaining the Acute Within-Person Relationship Between Physical Activity and Affect

Research has traditionally touted the "feel good" or "feel better" effects of participating in MVPA (Morgan, 1985). Several mechanisms have been proposed to explain this "feel good" effect, including the distraction hypothesis, which suggests that participating in physical activity provides a distraction from unpleasant stimuli leading to experiencing more favourable affect while physically active (Morgan, 1985; Paluska & Schwenk, 2000). In addition, physiological mechanisms, including the endorphin hypothesis and the monoamine hypothesis, have been proposed to explain the positive association between physical activity and affect (Morgan, 1985; Paluska & Schwenk, 2000; Peluso & Andrade, 2005). The monoamine hypothesis suggests that people experience more favourable affect during physical activity due to increased synaptic transmission of monoamines, including norepinephrine, dopamine, and serotonin, which may have antidepressant effects (Morgan, 1985; Paluska & Schwenk, 2000; Peluso & Andrade, 2005). The endorphin hypothesis suggests that beta-endorphins are released during physical activities, leading to feelings of euphoria and improvements in affect (Morgan, 1985; Paluska & Schwenk, 2000; Peluso & Andrade, 2005). More recently, researchers have theorised that increases in brain-derived neurotrophic factor (Dinoff et al., 2017; Szuhany et al., 2015) and the activation of the endocannabinoid system

(Brellenthin et al., 2017; Meyer et al., 2019) associated with engagement in MVPA may explain the positive association between physical activity and affect.

In support of the "feel good" effect of participating in MVPA, research has consistently shown that people experience more favourable affect following participation in MVPA (Yeung, 1996). For example, results from a meta-analysis showed a medium-sized positive effect on acute changes in positive-activated affect from pre-to-post participation in a single bout of MVPA (Reed & Ones, 2006). However, examining affect only before and after physical activity fails to capture the dynamic relationship between physical activity and affect and how affect changes during physical activity (Bixby et al., 2001). The association between physical activity and affect *during* physical activity may be different than the association between physical activity and affect *after* physical activity. For example, Bixby et al. (2001) suggested that although it is possible that affective states become more positive during physical activity and this improvement is maintained after completion of the physical activity, it is also possible that affective states worsen during physical activity but improve immediately after completing the physical activity, such that there is a rebound effect (Figure 2.1). This rebound hypothesis is consistent with the Opponent-Process theory (Solomon & Corbit, 1974), which suggests that the hedonic (i.e. pleasure-displeasure) response to a stimulus can be considered through two distinct or opposite processes. The *a* process is an immediate unconditioned hedonic response to a stimulus. In contrast, the *b* process is a delayed and slower response that occurs once the stimulus is terminated and the *a* process has stopped (Solomon, 1980). The *b* process has the opposite hedonic quality of the *a* process, therefore the *b* process will return an individual to their hedonic homeostasis or beyond (Solomon, 1980).

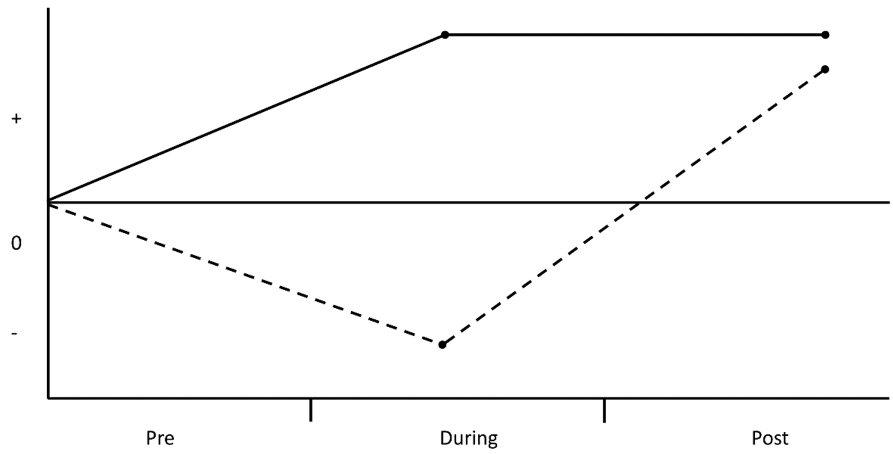

Figure 2.1 Illustration of the maintenance (solid line) and rebound (dashed line) models of the affective response to physical activity. Adapted from “Temporal dynamics and dimensional specificity of the affective response to exercise of varying intensity: differing pathways to a common outcome”, by W. R. Bixby, T. W. Spalding and R. D. Hatfield, 2001, Journal of Sport & Exercise Psychology, 23(1), p. 173. Copyright 2001 by Human Kinetic Publishers, Inc.

Given that research has consistently shown that there is a favourable association with affect from pre-to-post participation in a single bout of physical activity (Reed & Ones, 2006), if the rebound hypothesis were to hold true, it would be expected that there would be a negative association between physical activity and affect during physical activity. In support of the rebound hypothesis, research has shown that affect typically worsens during participation in strenuous physical activity before rapidly improving upon completion of the physical activity (Ekkekakis & Petruzzello, 1999). However, research has shown that there may be a positive association between physical activity and affect during light-intensity physical activities, and then affect remains stable following completion of light-intensity physical activity (Lochbaum et al., 2004). It is also possible that affect remains stable during light-intensity physical activity followed by a disparate improvement in affect following the completion of the physical activity (Bixby & Lochbaum, 2006). Therefore, unlike during more intense physical activities, during light-intensity physical activity, the relationship between physical activity and affect may more closely follow the maintenance hypothesis as proposed by Bixby et al. (2001). This suggests that the relationship between physical activity and affect may be intensity specific. One model that explains how physical activity intensity can explain the relationship between physical activity and affect is the Dual-Mode Model (Ekkekakis, 2003).

Dual-Mode Model of the Affective Response to Physical Activity

The Dual-Mode Model is based on the seminal work of Ekkekakis and Petruzzello (1999) on the acute relationship between aerobic physical activity and affect, which concluded that there was a dose-response relationship between physical activity duration and intensity on affect. Ekkekakis and Petruzzello (1999) suggest that higher intensity and greater duration lead to a more negative association between physical activity and affect during physical activities. Based on this work, a series of distinct phenomena were identified regarding the relationship between physical activity and valence (Ekkekakis, 2003). First, there is a uniform positive relationship between physical activity and valence during bouts of physical activity completed at a low intensity. Second, the relationship between physical activity and valence during moderate-intensity physical activity is characterised by inter-individual variability, with some individuals reporting a positive relationship between physical activity and valence while others report a negative relationship. Third, there is a uniform negative relationship between physical activity and valence during vigorous intensity physical activities. Empirical research supports these hypotheses, showing that the greatest variability in the relationship between physical activity and valence between individuals is during activities completed at moderate-to-vigorous intensities (Ekkekakis et al., 2011). Additionally, although the relationship between physical activity and valence *during* physical activity was intensity specific, research demonstrated that the relationship between physical activity and valence *after* physical activity are almost uniformly positive, regardless of intensity (Ekkekakis, 2003).

Based on this seminal work, the Dual-Mode Model was developed, which posits a dose-response pattern between physical activity intensity and valence (Ekkekakis, 2003). The model proposes that physical activity intensity should be considered in terms of an individual's ventilatory threshold (VT). The VT is defined as the physical activity intensity at which the increase in ventilation becomes disproportional to the increase in power or speed during physical activity (Svedahl & MacIntosh, 2003), or the stage where breathing becomes laboured. The term dual-mode refers to the two hypothesised influences that predict the relationship between physical activity and affect: cognitive and interoceptive influences. The model proposes that the relationship between physical activity and valence is the product of the interplay between cognitive processes and interoceptive cues from various receptors stimulated by physiological changes during physical activity (Ekkekakis, 2003).

The Dual-Mode Model proposes that light-intensity physical activity below an individual's VT presents no threat to an individual's physiological homeostasis, and therefore there is a low to moderate influence of cognitive factors on valence experienced during light-intensity physical activity (Ekkekakis et al., 2005). For vigorous-intensity physical activity completed above an individual's VT there is a strong influence of negative interoceptive factors resulting from physical activity-induced physiological changes, such as perceived muscle soreness or difficulty breathing (Ekkekakis et al., 2005). For physical activity completed at an individual's VT, cognitive factors are likely to have the greatest influence on the relationship between physical activity and valence (Ekkekakis et al., 2005). Therefore, cognitive factors may explain inter-individual variances in the relationship between MVPA and valence (i.e. why does the relationship between MVPA and valence differ between two individuals?). Additionally, given that there is no archetypical physical activity behaviour, and valence experienced during physical activity is likely a result of a multitude of situational appraisals (Backhouse et al., 2007), it may also be possible that cognitive factors explain intra-individual variance in the relationship between MVPA and valence (i.e. why is the relationship between MVPA and valence different for the same individual on two separate occasions?).

It is important to note that the Dual-Mode Model proposes how physical activity intensity, cognitive factors, and interoceptive cues influence the association between physical activity and valence. However, the association between physical activity and activation may differ. In fact, the association between physical activity intensity and activation during physical activity may be the opposite of that with valence, whereby more intense physical activities are associated with larger increases in activation during physical activity (Ekkekakis et al., 2008). Additionally, opposite to valence, there is likely a uniform negative association between physical activity and activation *following* participation in physical activities (Ekkekakis et al., 2008). Nevertheless, there may still be substantial inter- and intra-individual variations in changes in activation during a bout of MVPA (Backhouse et al., 2007). Therefore, in addition to valence, cognitive factors could explain variations in energetic arousal and tense arousal during MVPA.

Cognitive Factors and the Acute Within-Person Association Between Physical Activity and Affect

Given that cognitive factors have been theorised to explain variance in the relationship between MVPA and affect, there has been growing research into the influence of theory derived cognitive constructs on the relationship between MVPA and affect (Ekkekakis et al., 2013). Qualitative research has pointed to several cognitive factors that may explain variances in the relationship between MVPA and affect, including perceptions of ability, perceptions of control, self-determined motivation, sense of achievement, and perceived outcomes from being physically active (Rose & Parfitt, 2007; Rose & Parfitt, 2010). Similar findings have been observed in adolescents where perceptions of physical activity as being fun and enjoyable, individual perceptions of confidence, achievement and progression, and autonomous participation contributed to more favourable affect while physically active (White, Olson, et al., 2018). Alternatively, perceptions that a physical activity is too difficult, not finding a physical activity interesting, and being forced to participate in physical activity were found to contribute to an unfavourable affective experience when physically active (White, Olson, et al., 2018).

Self-Determination Theory

Several of the cognitive factors that are proposed to contribute to more positive affect during physical activity come from the Self-Determination Theory (SDT) (Ryan & Deci, 2000b) and its sub-theories, including the Basic Psychological Needs Theory (Ryan & Deci, 2000a). The SDT highlights the importance of self-regulation in the pursuit of human behaviours (Ryan & Deci, 2000b). It regards self-regulation in terms of motivation, which presents on a continuum from amotivation through extrinsic and intrinsic motivation (Figure 2.2). Intrinsic motivation is the motivation to pursue behaviours because of their novelty or challenge and to explore, learn and expand one's capacity (Ryan & Deci, 2000b). Extrinsic motivation refers to pursuing behaviours to attain an outcome distinct from the behaviour itself, and therefore, it contrasts intrinsic motivation (Ryan & Deci, 2000b). However, extrinsic motivations may vary in the degree to which they are internalised or the degree to with extrinsic motivations are integrated with one's sense of self (Deci & Ryan, 2008). Therefore, extrinsic motivations may vary from more externalised motivations including external regulation (i.e., motivated to receive an award or avoid a punishment), and introjected regulation (i.e., motivated to avoid guilt or to enhance ego), to more internalised motivations including identified regulation (i.e., motivated because participation in a behaviour is considered personally important), and integrated regulation (i.e., motivation because participation in a behaviour is congruent with one's values and needs). Finally, amotivation is a lack of intent to act which results in people not participating in behaviours or participating in behaviours without intent (Ryan & Deci, 2000b).

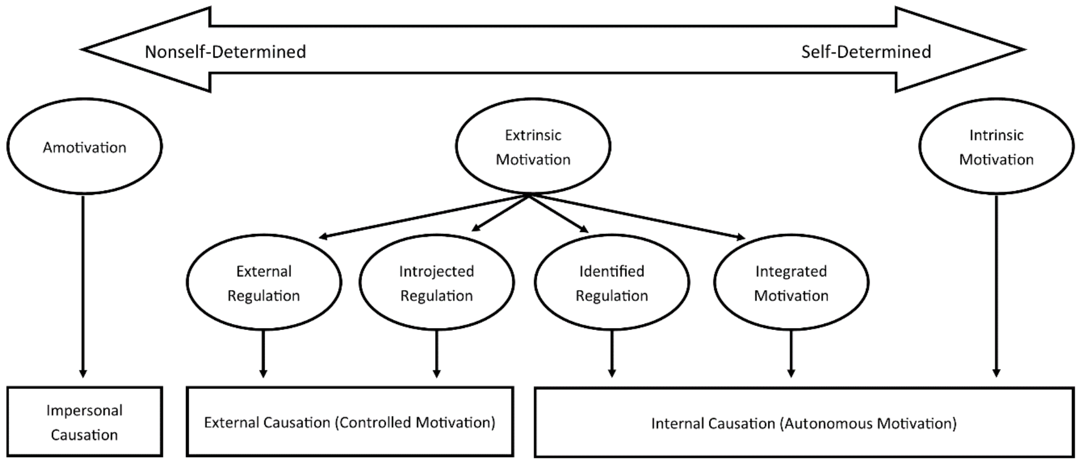

Figure 2.2 Illustration of the Self-Determination Theory. Adapted from "Self-Determination Theory and the facilitation of intrinsic motivation, social development, and well-being", by R. M. Ryan and E. L. Deci, 2000, American Psychologist, 55(1), p. 72. Copyright 2000 by American Psychological Association, Inc.

With the conceptualisation of internalisation of motivations, the focus of the SDT has shifted from differentiating between intrinsic and extrinsic motivations to differentiating between autonomous and controlled motivations (Deci & Ryan, 2008). Autonomous motivations include intrinsic, integrated and identified motivations, whereas controlled motivations include introjected and external motivations (Deci & Ryan, 2008). Amotivation is still considered separately as it describes no motivation or intention to participate in a behaviour (Deci & Ryan, 2008). The SDT suggests that the degree to which behaviours are autonomously motivated depends on the degree to which the basic psychological needs of competence, autonomy, and relatedness are fulfilled (Ryan & Deci, 2000a, 2000b). Optimally challenging behaviours (i.e. competence), behaviours that are volitional and completed with freedom (i.e. autonomy), and behaviours that make individuals feel connected with others (i.e. relatedness) are likely to be more autonomously motivated (Deci & Ryan, 2000).

Deci and Ryan (2008) suggest that having more autonomous motivations over a behaviour will lead to more adaptive outcomes following that behaviour. Therefore, the degree to which participation in physical activity is autonomously motivated and the basic psychological needs are satisfied may somewhat determine the psychological outcomes of participating in MVPA (Ryan et al., 2009; Teixeira et al., 2012). Having autonomy over physical activities may promote a sense of wellbeing by allowing participants to self-regulate behaviours and choose preferred physical activity modes and intensities which may lead to a more positive association between physical activity and affect (Ekkekakis, 2009). Perceived competence during physical activity may foster feelings of ability, accomplishment and satisfaction which also may be associated with more positive affective outcomes (Rose & Parfitt, 2007; Rose & Parfitt, 2010; White, Olson, et al., 2018). Additionally, feelings of relatedness during physical activity may be accompanied by feelings of connectedness, inclusion, and being cared for (Ryan et al., 2009). Therefore, self-determined motivation, autonomy, competence and task-self efficacy, and relatedness may be mechanisms that explain inter- and intra-individual variance in the association between physical activity and affect.

Self-Determined Motivation

Results from multiple experimental studies have shown that there is a correlation between intrinsic and identified motivation with valence during MVPA in samples of adolescents (Schneider & Kwan, 2013), young adults (Gillman & Bryan, 2016; Shin et al., 2014), and middle-aged women (Jones et al., 2017). Additionally, Jones et al. (2017) found that amotivation and externally regulated motivation were negatively correlated with valence during an aerobic exercise class. Together, these studies show that people who have more autonomous forms of motivation experience more positive valence during MVPA. There have also been some experimental studies that have shown that participants who reported more identified, integrated and intrinsic motivation to be physically active experienced greater levels of energetic arousal during MVPA in samples of university students (Lutz et al., 2003) and middle-age women (Jones et al., 2017). Both studies also found that amotivation and external motivation were negatively correlated with energetic arousal (Jones et al., 2017; Lutz et al., 2003). No studies were identified that examined whether self-determined motivation explained inter-individual variance in tense arousal during MVPA.

In addition to explaining variations between individuals, there is also some support that self-determined motivation is a mechanism that may explain intra-individual variation in valence experienced during MVPA. Results from one experimental study showed that within-person changes in motivational states toward more intrinsic motivations was positively related to within-person changes in valence during a bout of MVPA (Gillman & Bryan, 2016). Results from an EMA study also found that self-determined motivations moderated the within-person association between physical activity and valence in older adults, such that physical activity only had a positive within-person association with valence when participants reported average or above average levels of autonomous forms of motivation (Kanning & Hansen, 2016). Additionally, a daily diary study found that first-year university students reported significantly more positive valence during MVPA on days that they intended to be physically active, indicating that amotivation may contribute to a less positive valenced response to MVPA in daily life (Kwan et al., 2018). However, another ambulatory assessment study of university students found that self-determined motivations did not moderate the within-person association between physical activity and valence in daily life (Kanning et al., 2012).

Multiple EMA studies have also shown that self-determined motivation moderates the within-person association between physical activity and energetic arousal (Kanning et al., 2012; Kanning & Hansen, 2016). In an EMA study in a sample of university students, self-determined motivations augmented the association between physical activity and energetic arousal, such that the relationship between physical activity and energetic arousal was more positive when participants had more autonomous forms of motivation towards the activity (Kanning et al., 2012). These findings were replicated in an experience sampling study in a sample of older adults (Kanning & Hansen, 2016).

Unlike valence and energetic arousal, evidence suggests that self-determined motivation does not positively moderate the within-person association between physical activity and tense arousal. In fact, one random sampling EMA study involving university students found that self-determined motivations augmented the association between physical activity and tense arousal such that more autonomously motivated physical activity was associated with greater increases in tense arousal (Kanning et al., 2012). In a separate experience sampling study, Kanning and Hansen (2016) found that self-determined motivations did not moderate the association between physical activity levels and tense arousal in older adults.

Autonomy

A longitudinal diary study found that autonomous orientations towards physical activity at baseline were positively related to recalled valence during MVPA in daily life throughout the study period in a sample of undergraduate university students (Kwan et al., 2011). This indicates that autonomy may explain inter-individual variations in valence during MVPA in daily life. However, in contrast to results from the daily life study, results from an experimental study found no significant correlation between perceived autonomy and in-task valence during a bout of self-selected or prescribed MVPA in a sample of women (Rose & Parfitt, 2012). No studies were identified that examined whether autonomy explained inter-individual variations in energetic or tense arousal during MVPA.

When considering intra-individual variations in valence, multiple experimental cross-over trials have manipulated autonomy by having participants participate in a bout of MVPA at a prescribed intensity and a bout of MVPA at a self-selected intensity (Rose & Parfitt, 2012; Vazou-Ekkekakis & Ekkekakis, 2009). Although participants reported significantly greater autonomy during the self-selected bouts of MVPA, there was no differences in valence reported during the self-selected and imposed physical activity conditions in each of these studies (Rose & Parfitt, 2012; Vazou-Ekkekakis & Ekkekakis, 2009). In contrast to valence, Vazou-Ekkekakis and Ekkekakis (2009) found that energetic arousal increased significantly more during the self-selected physical activity than the bout of MVPA at a prescribed intensity. However, Rose and Parfitt (2012) found that energetic arousal increased during both self-selected and prescribed bouts of MVPA and that there was no significant intra-individual variation in energetic arousal between conditions. Additionally, in one of the studies, it was found that changes in tense arousal during MVPA did not differ between the self-selected and prescribed conditions (Vazou-Ekkekakis & Ekkekakis, 2009).

Competence and Task Self-Efficacy

Experimental studies have shown that participants with greater competence and task self-efficacy report more favorable valence during MVPA in samples of adolescents (Robbins et al., 2004), and women (Rose & Parfitt, 2012). Interestingly, multiple studies have also shown that ratings of self-efficacy that were taken during or immediately after completing a bout of MVPA were correlated with valence during the physical activity, but ratings of self-efficacy taken before completing the MVPA were not (Barnett, 2013; Welch et al., 2010). This suggests that the relationship between self-efficacy and valence may be stronger when individuals have a more temporally prominent experience to base appraisals of self-efficacy on. Although several experimental studies indicated that competence and task self-efficacy explained inter-individual variations in valence during MVPA, some experimental studies also indicated that there was a null correlation between task self-efficacy and valence during MVPA in samples of adults (Ekkekakis et al., 2010; Focht et al., 2007). Additionally, in their longitudinal study of members of a group exercise class, Sudeck et al. (2016) found a non-significant between-person relationship between average level of perceived competence and valence reported over multiple classes in adults.

Unlike valence, there was no evidence that competence and task-self-efficacy explain inter-individual variations in energetic arousal during MVPA, with several experimental studies finding a non-significant correlation between competence and task self-efficacy with levels of energetic arousal in adults (Barnett, 2013; Ekkekakis et al., 2010; Focht et al., 2007). Similarly, in their longitudinal study of exercise class members, Sudeck et al. (2016) did not find a significant between-person association between competence and energetic arousal reported during the exercise classes.

Although unrelated to energetic arousal, research indicates that people with more positive perceptions of competence and task-self efficacy may experience less tense arousal during MVPA. For example, experimental studies have shown that university students (Blanchard et al., 2002), and women (Barnett, 2013) who reported feeling more competent than others reported feeling less tense during a bout of MVPA. Similarly, Vlachopoulos et al. (1996) found an inverse relationship between competence and tense arousal following physical activity in a sample of adolescents. Additionally, in their longitudinal study, Sudeck et al. (2016) found that exercise class members who reported feeling more competent on average reported feeling less tense during the exercise classes on average. However, there are also several experimental studies which have found that competence and task self-efficacy are not correlated with tense arousal during MVPA (Bosoian & Rejeski, 1994; Focht et al., 2007; Raedeke et al., 2009).

Considering intra-individual variations in valence during MVPA, one experimental study which had participants participate in three different exercise conditions found a significant within-person association between perceived competence and valence during MVPA (Schmid et al., 2021). Additionally, in a longitudinal study, it was found that when participants in a group exercise class reported greater levels of perceived competence after an exercise session, they reported significantly more positive valence during the session (Sudeck et al., 2016). Alternatively, in an experience sampling study involving older adults, Kanning and Hansen (2016) found that competence did not moderate the within-person association between physical activity and valence in daily life.

In their study of participants in exercise classes, Sudeck et al. (2016) also found that participants reported more energetic arousal during the exercise class when they felt more competent during the class. However, inversely, an experience sampling study of older adults found that that participants reported less energetic arousal during physical activities that they felt more competent in (Kanning & Hansen, 2016). Additionally, results from multiple studies indicate that competence does not explain intra-individual variations in tense arousal during physical activity (Kanning & Hansen, 2016; Sudeck et al., 2016).

Relatedness

There is sparse research examining whether relatedness is a mechanism that explains variations in the relationship between physical activity and affect. In a longitudinal study of members of a fitness centre, researchers found a significant positive within-person association between perceptions of group entitativity (e.g., how much an exercise session felt like a group effort) and recalled affective valence during the exercise class (Graupensperger et al., 2019). This study also found a significant between-person association between perceived entitativity and recalled valence during the exercise class, such that those who reported more positive perceptions of entitativity on average had a more positive valenced response during the exercise class (Graupensperger et al., 2019). Similarly, a cross-sectional study of participants in a group exercise class found that perceptions of group entitativity were positively correlated with recalled feelings of pleasure during the exercise class (Evans et al., 2019).

Overview of Cognitive Mechanisms Explaining Variations in the Relationship Between Physical Activity and Affect

In summary, there is some support in the literature demonstrating that cognitive factors explain inter-individual variations in the relationship between MVPA and affect. Research has consistently shown that individuals with more self-determined motivation to be physically active experience more positive valence and greater energetic arousal during MVPA. Additionally, there several studies showing that individuals with greater perceived competence experience more positive valence and less tense arousal during MVPA. There is also limited research indicating that relatedness explained variations in valence experienced during MVPA between people. The influence of autonomy remains unclear.

Like inter-individual variation, results from multiple studies show that self-determined motivation explains intra-individual variations in valence and energetic arousal during MVPA. Participants report more positive valence and greater energetic arousal when they participate in more autonomously motivated physical activities. Some research indicates the participants may also report more positive valence when they feel more competent about participating in MVPA. There is less consistent evidence regarding the influence of autonomy and relatedness on the within-person association between MVPA and affect.

Domain Specific Within-Person Association Between Physical Activity and Affect

Young people may participate in several different domains of MVPA, including recreation, active travel, as part of the school curriculum (e.g. Physical Education), at home (e.g. while completing household chores or gardening) or as part of their casual employment. Researchers have hypothesised that the type or domain of physical activity young people participate in may moderate the association between physical activity and affect (Lubans et al., 2016; White, Parker, et al., 2018). Given that cognitive factors may explain variations in affect experienced during MVPA, physical activities that promote intrinsic motivation, autonomy, competence, and relatedness may have a more positive association with affect in young people.

Recreational physical activities may be more autonomously motivated, provide a distraction from stress, allow for mastery, promote social interactions and improve self-esteem to a greater extent than other domains of physical activity (Teychenne et al., 2020). For example, qualitative research has shown that adolescents are more likely to describe enjoyment, autonomy, confidence, and a distraction from stresses as a reason for participation in recreational physical activity compared to other domains of physical activity, such as active travel (White, Olson, et al., 2018). Cross-sectional research has also found that autonomous motivation was positively correlated with levels of self-reported recreational physical activity in adolescents (White, Parker, et al., 2018). In contrast, autonomous motivations were not related to levels of self-reported active travel, suggesting that recreational physical activities may be more autonomously motivated (White, Parker, et al., 2018). This may be because non-recreational physical activities such as household physical activities or active travel are often completed spontaneously or non-consciously, rather than intentionally, and therefore may lack any form of motivation (Kanning et al., 2013). Additionally, reasons such as enjoyment, fun, personal pleasure, participating with friends, and participating in physical activity because it is considered personally important have been found to be important reasons for participating in recreational physical activities in adolescents (Butt et al., 2011; Casey et al., 2009; Iannotti et al., 2013; Wold et al., 2016). In comparison, environmental factors such as street connectivity, having parks along routes, and perceived safety may be more strongly associated with active travel behaviours in adolescents than cognitive factors (Leslie et al., 2010; Wang et al., 2017). Additionally, distance to destinations is significantly related to active travel behaviours, such that those who live closer to destinations are more likely to use active modes of travel (Duncan et al., 2016; Van Dyck et al., 2010). Therefore, adolescents' reasons for participating in active travel may be more likely to include its practicality as a mode of transport (Simons et al., 2013). Consequently, it is possible that the relationship between MVPA and affect may be more positive for recreational physical activities than other domains of physical activity, including active travel and household physical activities.

There is some research that shows that the relationship between MVPA and affect may be domain specific. A qualitative study found that adolescents perceived positive affect to be associated with physical activity during leisure-time more than active travel to school or physical activity during Physical Education (White, Olson, et al., 2018). Recently, a study that used experience sampling and daily reconstruction methods examined the association between device-measured incidental physical activity, self-reported exercise, and self-reported sport with valence, energetic arousal and tense arousal in adolescents (Koch et al., 2020). Researchers found that the within-person relationship between physical activity and affect differed based on the type of physical activity. They found that device-measured incidental physical activity had a positive within-person association with valence and energetic arousal but was unrelated to tense arousal. Similarly, participants reported more positive valence when participating in unorganized exercise compared to not participating in any physical activity at all. However, participants also reported more tense arousal when participating in unorganized exercise, and significantly less energetic arousal when participating in organized sports. Although this study showed that different types of physical activities may be differently associated with affect in adolescents, it did not compare domain specific associations between recreational physical activity, active travel, and household physical activity with affect.

There have also been some studies that have examined the difference in the within-person association between physical activity and affect between different types of physical activity in young adults. An experience sampling study which examined the within-person association between device-measured exercise and non-exercise physical activity with affect in young adults' daily lives showed that the association between physical activity and affect might differ based on whether the physical activity was purposeful exercise or an incidental non-exercise physical activity (Reichert et al., 2017). Specifically, exercise had a positive association with affective valence and an inverse association with tense arousal, whereas non-exercise physical activity had a positive association with energetic arousal and tense arousal (Reichert et al., 2017). However, this study also did not compare distinct domains of MVPA. Another EMA study of young adults examined whether engaging in MVPA during leisure time or while at work moderated the association between physical activity and affect (Kanning, 2013). They found no difference in the within-person association between physical activity and valence, energetic arousal, or tense arousal when participants reported being in leisure-time or when they were at work. Although this study examined whether being in leisure-time moderated the association between physical activity and affect, it did not specifically examine the association between recreational physical activity and affect. To date, no EMA studies have examined whether the within- and between-person association between physical activity and affect differs for recreational physical activity, active travel and household physical activity for adolescents.

Contextual Influences on The Acute Within-Person Relationship Between Physical Activity and Affect

In addition to different domains of physical activity, there is no archetypical physical activity context. Therefore, it is possible that the context in which the physical activity occurs could influence the association between physical activity and affect (Backhouse et al., 2007; Lubans et al., 2016). The physical activity context consists of the physical environment and social context in which the physical activity occurs.

Physical Environment and Affect

Biophilia Hypothesis

One perspective to understand the potential benefits of being physically activity in natural environments on affect is the evolutionary perspective. Central to the evolutionary perspective is the Biophilia hypothesis, which can be defined as the "innately emotional affiliation of human beings to other living organisms" (Wilson, 1993; p. 31). It is believed that this affiliation is an evolutionary adaptation owing to the advantages afforded by life and life like processes in human beings' struggle to adapt, persist and thrive as a species (Kellert, 1993). This hypothesis proposes that humans have a naturalistic tendency to pay attention to, associate with, and respond positively to natural environments (Kellert, 1993). It is suggested that people may have a number of different biophilic responses to natural environments, including stress reduction, attention restoration, like/approach impulses, and higher-order cognitive functioning (Ulrich, 1993). Given these possible biophilic responses, contact with nature during physical activity has the potential to be positively associated with affect.

Attention Restoration Theory

A theory that explains the potential psychological benefits of exposure to natural environments is the Attention Restoration Theory which proposes that natural environments can easily hold an individual's attention and overcome the effects of directed attention fatigue and reduce mental fatigue (Kaplan, 1995). Directed attention is a non-automatic process where the attentional focus is controlled, goal-driven, and not intrinsically motivated (Kaplan & Berman, 2010). Directed attention fatigue occurs during times of prolonged mental effort where an individual is required to pay attention to a task for an extended period (Kaplan, 1995) and can lead to worsening affect (Kaplan, 1995; Watanabe et al., 2019). In contrast, involuntary attention is effortless, stimulus-driven, and intrinsically motivated (Kaplan & Berman, 2010). During moments of involuntary attention, an individual's attentional and mental capacity can recover and thus, affect may improve (Kaplan, 1995).

In addition to directed and involuntary attention, there are two key attentional focus styles in the context of physical activity, association and dissociation (Masters & Ogles, 1998). Association is characterised by focusing on and monitoring bodily sensations during physical activity, whereas dissociation is characterised by focusing on external stimuli (Masters & Ogles, 1998). Tenenbaum and Hutchinson (2012) suggests that as physical activity intensity increases, people begin to shift towards a more associative attentional focus. However, they also suggest that maintaining dissociative attentional focus during more intense physical activities may improve an individual's ability to tolerate MVPA and therefore experience more favourable affect while physically active. Therefore, physical environments that can hold an individual's attention may prevent them from paying attention to bodily sensations while physically active and potentially lead to more favourable affect during physical activities.

The Attention Restoration Theory proposes that there are four components of restorative environments that can encourage involuntary attention and restore attentional and mental capacity: 1) being away from daily tasks; 2) fascinating; 3) perceived as expansive; and 4) are compatible with tasks that individuals are intrinsically motivated to participate in (Kaplan, 1995). It is suggested that natural environments have restorative properties because they have a variety of fascinating objects that readily hold an individual's attention, they provide a sense of "getting away", and they provide a setting for a wide range of enjoyable and interesting activities (Kaplan, 1995). Even relatively small natural areas can be perceived as expansive (Kaplan, 1995). Multiple systematic reviews provide support for the attention restoration benefits of natural environments (Ohly et al., 2016; Stevenson et al., 2018). Even urban greenspaces have been shown to have attention restoration potential (Amicone et al., 2018; Tyrväinen et al., 2014).

Stress Reduction Theory

Another theory that explains the psychological benefits of exposure to natural environments is the Stress Reduction Theory which proposes that exposure to unthreatening natural settings may reduce stresses that people accumulate in everyday life (Ulrich et al., 1991). It is suggested that stress reduction may occur for several reasons, including human's evolutionary affiliation with nature, the lack of stress-inducing external stimulants in natural environments, and the attention restoration benefits of nature, which may also promote stress reduction (Ulrich et al., 1991). Ulrich (1983) suggests that the process through which natural environments can reduce stress in individuals is a combination of non-conscious changes in affect due to exposure to natural environments and cognitive evaluations of an environment that can produce changes in an individual's physiological arousal and subjective feelings. There is strong empirical support for the stress reduction hypothesis (Feda et al., 2015; Kondo et al., 2018; Mennis et al., 2018; Van den Berg et al., 2014).

Ecological Dynamics Framework

In addition to evolutionary theories that explain the psychological benefits of exposure to natural environments, the benefits of natural environments on affect may be understood through an ecological dynamics framework (Araújo et al., 2019). The ecological dynamics framework suggests that experiences are determined through a person-environment relationship, whereby there is a dynamic and complex interaction between an individual and the environment in regulating behaviours and outcomes (Araújo et al., 2019). These interactions depend upon affordances provided by an environment. Affordances are the properties of an environment that invite certain behaviours (Araújo et al., 2019; Gibson, 1986; Yeh, Stone, Churchill, Brymer, et al., 2016). These affordances interact with individual, task, and environmental constraints to shape behaviours and outcomes (Brymer et al., 2014; Yeh, Stone, Churchill, Wheat, et al., 2016). Therefore, how individuals perceive and utilise affordances in an environment is relative to their existing constraints (Brymer et al., 2014). For example, the affordances provided by the ocean will differ between an experienced surfer and an inexperienced swimmer.

The ecological dynamics approach suggests that natural environments are positively related to affect because they afford a greater diversity of behaviours that can promote wellbeing (Araújo et al., 2019). Whereas manufactured environments are produced for an intended purpose, and therefore present a limited number of affordances, natural elements have no single intended purpose, and the complexity of natural environments thus allows for greater creativity in behaviours and more opportunities to test physical skills (Araújo et al., 2019; Brymer et al., 2014). Additionally, manufactured environments often present stable and sterile environments that provide limited affordances to encourage psychological responses (Yeh, Stone, Churchill, Wheat, et al., 2016). Alternatively, natural environments are complex and varying and provide affordances for various physical activities and psychological responses (Brymer et al., 2014; Yeh, Stone, Churchill, Wheat, et al., 2016). Therefore, environments with more natural elements may invite more varied physical opportunities and more positive psychological responses than environments with fewer natural elements (Yeh, Stone, Churchill, Wheat, et al., 2016). In support of this, a meta-analysis of studies on emerging and young adults found that interacting with natural environments is associated with moderate increases in positive affect and small but significant decreases in negative affect (McMahan & Estes, 2015).

Influence of the Physical Environment on the Acute Within-Person Association Between Physical Activity and Affect

There are several ways in which the benefits of physical activity may be enhanced or diminished by the physical environment (Shanahan et al., 2016). The physical environment may have an additive effect when it has a positive association with affect independent of levels of physical activity, a sub-additive impact on affect when the physical environment has a negative association with affect independent of levels of physical activity, or a synergistic effect where the physical environment and levels of physical activity interact to determine affect (Shanahan et al., 2016). Highlighting the enhanced benefits of being physically active outdoors, multiple systematic reviews have shown that the benefits of participating in physical activity on wellbeing may be greater when the physical activity takes place outdoors and in natural environments (Bowler et al., 2010; Lahart et al., 2019; Thompson Coon et al., 2011).

Considering the constructs from the three-dimensional model of affect (Leonhardt et al., 2016), a randomised control trial found that adults randomised to complete exercise classes in an outdoor gym at a local park reported significantly greater levels of valence during the classes, controlling for baseline valence, than those randomised to compete the classes in an indoor gym (Lacharité-Lemieux et al., 2015). Experimental cross-over studies have also examined the added within-person effects of being physically active outdoors on valence in adults in multiple outdoor environments, including parks and similar natural environments (Frühauf et al., 2016; Niedermeier et al., 2017), athletic tracks (Dasilva et al., 2011; Krinski et al., 2017), and urban environments (Focht, 2009). In each of these studies it was found that ratings of valence were significantly more positive when participants were physically active outdoors compared to when participants completed MVPA at a similar intensity indoors. Additionally, one study compared valence while walking in natural and urban environments and found that physically active adults reported the greatest pleasure during physical activity when walking in natural environments (Kinnafick & Thøgersen-Ntoumani, 2014). However, one randomised controlled trial found that there was no significant difference in the change in valence from pre-to-post completing a circuit of aerobic and anaerobic physical activities between adolescents randomised to complete the circuit indoors, at a park and at a nature reserve (Wade et al., 2020). Additionally, in their study, Turner and Stevinson (2017) found that recreational runners' ratings of valence did not differ during physical activity when completing running at maximal effort in a natural outdoor environment or indoors on a treadmill. Results from an experience sampling study also showed that inactive adults did not report more positive valence while walking outdoors in daily life compared to walking indoors (Boyle et al., 2020).

There is less abundant evidence to indicating added benefits of being physically active in natural environments on energetic arousal. Multiple randomized controlled trials showed that participants randomized to exercise outdoors and indoors did not report significantly different levels of energetic arousal during MVPA (Lacharité-Lemieux et al., 2015), or changes in energetic arousal from pre-to-post being active (Wade et al., 2020). One cross-over study found that physically active young women reported greater energetic arousal when physically active outdoors (Focht, 2009), however, other studies found no difference in energetic arousal during physical activity when participants were active outdoors compared to when active indoors (Niedermeier et al., 2017; Turner & Stevinson, 2017), and one study found energetic arousal was greater during physical activity when physically inactive women were active indoors (Krinski et al., 2017). Additionally, a single study found no difference in changes in levels of energetic arousal from pre-to-post physical activity when inactive adults when active in natural and urban environments (Kinnafick & Thøgersen-Ntoumani, 2014).

There is also inconsistent evidence regarding the added benefits of being physically active outdoors on tense arousal. Lacharité-Lemieux et al. (2015) found a significant time by condition interaction on tranquillity following physical activity in their randomised controlled trial. They found that tranquillity following the physical activity sessions increased from the first week to the last week for women randomised to the outdoor training condition, whereas tranquillity following physical activity decreased from the first week to the last week of the study for participants randomised to the indoor training group. However, another study involving female university students found that participants randomised to complete a bout of MVPA indoors or outdoors did not differ in changes in calmness from pre-to-post physical activity (Plante et al., 2007). A decrease in calmness was observed in all conditions. Similarly, another study found that changes in adolescents and young adults male's ratings of tranquillity from pre-to-post exercise did not differ between when participants completed a bout of MVPA indoors and outdoors (Reich & Queathem, 2020). When considering the difference between urban and natural environments, Butryn and Furst (2003) found that ratings of tranquillity significantly increased from pre-to-post completing a four-mile run in a sample of active women when completed in a natural environment, but not an urban environment. However, other studies involving inactive adults (Kinnafick & Thøgersen-Ntoumani, 2014) and young adults (Johansson et al., 2011) found that changes in participants' rating of tense arousal from pre-to-post a bout of MVPA did not differ when completing the task in a natural environment and a built-up urban environment.

Although very few studies have examined the added benefits of being physically active in natural environments on valence, energetic arousal, and tense arousal in adolescents, some studies have examined the added benefits of being physically active in natural environments on positive and negative affect and moods in young people. One EMA study found that children and adolescents reported significantly more positive affect when active outdoors than when active indoors in daily life (Dunton, Liao, Intille, Wolch, et al., 2011). However, this study also found no difference in levels of negative affect reported during physical activities completed indoors and outdoors. Additionally, in an experimental study involving athletic adolescents, researchers found that there was no significant difference in changes in positive affect or negative affect following a bout of MVPA completed indoors and outdoors in a natural setting (Reich & Queathem, 2020). However, it is important to note that the participant's average heart rate was significantly higher during the outdoor session than the indoor session, which may have confounded the results.

There is also limited evidence suggesting a synergistic effect where physical activity and physical environments interact to determine affect experienced while physically active. In their EMA study, Dunton et al. (2015) found the physical environment moderated the relationship between physical activity and negative affect in adults. They found that being physically active outdoors had a stronger inverse within-person association with negative affect than being physically active indoors. However, this study found no interaction between physical activity and environment on positive affect. Additionally, in an experimental cross-over study involving physically inactive adults, results showed that feelings of valence and energetic arousal were significantly greater when walking than sitting in both urban and natural environments, indicating no synergistic effect between the physical environment and MVPA (Kinnafick & Thøgersen-Ntoumani, 2014). It was also found that being physically active did not interact with the physical environment to determine changes in tense arousal from pre-to-post exercise (Kinnafick & Thøgersen-Ntoumani, 2014). To the author's knowledge, no studies have examined whether there is a synergistic effect between physical activity and the environment on affect in adolescents.

Social Context and Affect

In addition to the physical environment, the social context may also influence the affect experienced during physical activity. Like the physical environment, the social context of a physical activity could have an additive, sub-additive, or synergistic effect with physical activity on affect. Multiple authors have suggested that social resources, including contexts, relationships and interactions predict affect (Sbarra & Coan, 2018; Uchino & Eisenberger, 2019), may therefore directly influence an individual's psychological states (Cohen, 2004). Alternatively, social resources may influence people's affect through several intermediary pathways.

Stress Reduction Hypothesis

It has been hypothesised that social interactions may influence affect by reducing the impact of stress (Cohen et al., 2000). Information-based models suggest that social networks provide information about ways to cope with stressful events which can help someone to reappraise the stressfulness of an event and reduce the negative affective response (Cohen, 1988). Emotional support or assisted coping during stressful events may also increase an individual's perception of self-esteem and feelings of personal control, and this may dampen the negative affective response typically associated with stressful events (Cohen, 1988; Cohen et al., 2000). Alternatively, social interactions may improve an individual's self-perception by providing instrumental or informational support that can aid an individual to complete difficult tasks and overcome problems (Cohen, 2004). Therefore, people may experience less acute stress reactions during MVPA when it is completed with someone else. Additionally, informational support from others may allow individuals to avoid stressful situations altogether and therefore avoid negative experiences (Cohen, 1988).

Physiological Hypothesis

Social interactions may also improve an individual's affective state by eliciting physiological changes. Social support may elicit positive physiological changes such as a reduction in blood pressure, heart rate, and stress hormones in response to acute stress, which subsequently impact an individual's affective state (Uchino, 2006; Umberson et al., 2010). Therefore, it may be possible that participants may experience less severe unpleasant physiological changes during physical activities when they are completed with others.

Cognitive Evaluation Theory

The Cognitive Evaluation Theory, a sub theory of the SDT, outlines the social psychology of intrinsic motivation, and explains how the social context can impact on intrinsic motivation, and thus affect, during physical activities (Ryan et al., 2009). The social context may support intrinsic motivation for physical activity by providing autonomy support, competence support, and relatedness support (Hagger & Chatzisarantis, 2007; Ryan et al., 2009; Wilson et al., 2008). For example, other people may promote competence by providing positive feedback throughout an activity or promoting a mastery environment, others may thwart autonomy by being controlling or coercive, and being included by others during an activity may promote relatedness (Ryan et al., 2009).

Influence Of the Social Context on the Acute Within-Person Association Between Physical Activity and Affect

There is some support for an additive benefit to being physically active with others with an experimental study (Casado et al., 2019) and an experience sampling study (Boyle et al., 2020) both showing that people experience more positive valence when physically active with others. Additionally, Casado et al. (2019) found that participants' blood lactate concentration was significantly lower when participating in the group condition than the alone condition, potentially providing support to the physiological hypothesis. However, there may be a sub-additive effect of being physically active with others on valence for some populations. In a study of inactive young women with higher than average levels of social physique anxiety, researchers found that participants reported significantly greater valence when exercising alone compared to exercising in public with others, even when controlling for perceived negative judgments by others about their physique (Focht & Hausenblas, 2006).

There has also been research showing there may be a synergistic effect between the social environment and physical activity on valence in adults. One EMA study involving mothers found that although physical activity did not have a significant within-person association with happiness, there was a significant positive within-person association between being active together with their children and happiness (Kanning et al., 2020). This indicates that the presence of their child augmented the association between physical activity and happiness. However, multiple experience sampling studies with older adults have found that whether participants are alone or with someone else did not moderate the within-person relationship between physical activity and valence (Cabrita et al., 2017; Kanning & Hansen, 2016).

With regards to energetic arousal, multiple experimental studies found that there was no significant difference in changes in energy from pre-to-post exercise between participants randomised to complete a bout of MVPA with a friend, and those randomised to complete the walk alone in a sample of undergraduate students (Plante et al., 2007; Plante et al., 2011). Additionally, considering the synergistic effect of social contexts, in their experience sampling study, Kanning and Hansen (2016) found that being with someone else or alone did not moderate the within-person association between physical activity and energetic arousal in a sample of older adults.

For tense arousal, one experience sampling study showed that the social context moderated the association between physical activity and tense arousal in a sample of older adults (Kanning & Hansen, 2016). Researchers found that physical activity was associated with experiencing more tense arousal only when participants were alone. A separate EMA study involving mothers found that although mothers reported more tense arousal when they participated in greater levels of physical activity, there was a significant inverse within-person association between being active together with their children and tense arousal, indicating that the presence of their child reversed the association between physical activity and tense arousal (Kanning et al., 2020). However, there may also be a sub-additive effect of being physically active with others on tense arousal. Multiple studies involving young adults found that changes in feelings of calmness and tranquillity from pre-to-post exercising were significantly less favourable when exercising with others than when exercising alone (Focht & Hausenblas, 2006; Plante et al., 2007; Plante et al., 2011). There have also been studies that have shown no difference in changes in tranquillity and calmness when exercising with others and alone (Johansson et al., 2011; Martin Ginis et al., 2007).

As well as the concepts from the three dimensional model of affect, there has been a study that has examined the synergistic effect of the social environment on the relationship between MVPA and positive and negative affect in adults' daily lives (Dunton et al., 2015). This study showed that being physically active with someone else augmented the positive association between physical activity and positive affect. However, the social context did not moderate the association between MVPA and negative affect.

To the author's knowledge, no studies have examined the influence of the social context of physical activities on valence, energetic arousal or tense arousal in children or adolescents. However, Dunton, Liao, Intille, Wolch, et al. (2011) did examine whether positive and negative affect reported during MVPA differed based on social context. They found that children reported significantly less negative affect when physically active with friends or family than when active alone in daily life. But they also found no difference in positive affect when active with others and alone in daily life. Given that adolescents assign high affective salience to social interactions (Lamblin et al., 2017), more research to understand the influence on social contexts on the relationship between physical activity and affect in adolescents is needed.

Overview of Contextual Mechanisms Explaining Variations in the Relationship Between Physical Activity and Affect

Although few studies have examined the added benefits of being physically active outdoors on valence in young people, there is strong evidence from studies in adults supporting the added benefits of participating in MVPA outdoors rather than indoors and in a natural environment than urban environments on valence. Some research also supports the added benefits of being physically active outdoors on energetic and tense arousal in young people. Few studies have examined the synergistic effects of the physical environment on the within-person association between MVPA and affect in daily life.

There is limited research examining the influence of social contexts on the association between MVPA and affect in adolescents and mixed findings regarding the effect of social context on the relationship between MVPA and adult's affect. Research indicates that there may be added benefits of being physically active with others on valence; however, there may be a sub additive effect in specific populations (e.g., people with social physique anxiety). Additionally, results from previous studies suggest there may be a sub additive effect of being physically active with others on tense arousal and there does not appear to be an additive or sub additive effect of being physically active with others on energetic arousal. However, the effect of the social context on tense arousal may be complex, as some EMA studies show there may also be a synergistic effect of the social context on the relationship between MVPA and tense arousal such that there is an inverse within-person association between MVPA and tense arousal only when the activity is completed with others. The evidence is less clear concerning a synergistic effect of the social context on the association between MVPA and valence and energetic arousal. Given the potential impact of the physical environment and social context on the within-person association between MVPA and affect in adolescents, and the limited research evidence to date, more research is needed to examine how the physical environment and social context influence the relationship between MVPA and affect in adolescents' daily lives.

Relationship between Physical Activity and Subjective Wellbeing in Adolescents

In addition to understanding the acute within-person association between physical activity and integral affect, it is important to consider how physical activity over longer periods is associated with subjective wellbeing in adolescents. It has been hypothesised that subjective wellbeing may be influenced by top-down, or time-invariant, and bottom-up, or time-varying, influences (Diener, 1984). Therefore, physical activity may have a top-down (i.e. usual levels of physical activity), or bottom-up (i.e. daily levels of physical activity) influence on subjective wellbeing (Maher et al., 2013). Examining the between-person and daily within-person associations between physical activity and wellbeing can illustrate whether physical activity is associated with incidental affect experienced in all aspects of daily life, not just affect experienced in the context of physical activity. Additionally, examining associations over longer periods allows for examination with satisfaction with life which may be less temperamental than affect, but still exhibit variability from day-to-day within individuals (Gadermann & Zumbo, 2007; Heller et al., 2006).

Between-Person Relationship between Daily Physical Activity and Subjective Wellbeing

Multiple recent systematic reviews have examined the between-person association between physical activity and subjective wellbeing (Buecker et al., 2020; Rodriguez-Ayllon et al., 2019; Wiese et al., 2018). For example, a recent comprehensive meta-analytic review of correlational studies involving healthy populations of all ages found that there was a small-to-moderate and significant correlation between physical activity and subjective wellbeing (Buecker et al., 2020). Another meta-analysis found a small but significant positive correlation between leisure-time physical activity and satisfaction with life and positive affect, but not negative affect, in samples of working adults (Wiese et al., 2018) Additionally, results from a recent systematic review of longitudinal and cross-sectional studies found consistent evidence of a positive association between physical activity and satisfaction with life and an inverse association between physical activity and incidental negative affect in children and adolescents (Rodriguez-Ayllon et al., 2019). However, this review only identified a single study that examined the association between physical activity and incidental positive affect in adolescents, in which a positive association was observed.

A recent study not included in the review by Rodriguez-Ayllon et al. (2019) suggests that there may be a curvilinear association between vigorous-intensity physical activity and incidental positive and negative affect in adolescents (Costigan et al., 2019). Results indicated that there is a favourable association between vigorous-intensity physical activity and incidental positive and negative affect for levels of vigorous physical activity up to about 37 minutes per day. However, engaging in more than this amount of vigorous-intensity physical activity per day may be associated with less favourable incidental affect. Additionally, results from this study indicated that neither light- nor moderate-intensity physical activity were associated with incidental positive or negative affect. Another meta-analysis of cross-sectional, longitudinal and experimental studies of children, adolescents and adults showed that the association between physical activity and positive mental health outcomes, including incidental affect and satisfaction with life, might be domain-specific (White et al., 2017). Researchers found that leisure-time physical activity and active travel were positively associated with mental health, which included affect and satisfaction with life, whereas household physical activity, school sports and Physical Education were not.

In addition to cross-sectional and longitudinal studies, EMA and daily diary studies can use the average of multiple responses to examine the between-person association between physical activity and subjective wellbeing in young people. EMA and daily diary studies have the advantage of providing a detailed overview of adolescents' lived experiences of affect and satisfaction with life in daily life based on multiple intensive assessments, rather than the single-assessment overview provided by cross-sectional studies (Russell & Gajos, 2020; Shiffman et al., 2008). This provides a more detailed description of affect as it was experienced rather than as it was remembered (Russell & Gajos, 2020). Additionally, examining sate life satisfaction over multiple days may be more appropriate for examining the impact of situational predictors, such as behaviours of daily life, than a single measure of trait life satisfaction that is likely predicted by more stable forces, such as personality (Jayawickreme et al., 2017a, 2017b).

There have been multiple EMA studies which have examined the between-person association between physical activity and incidental positive affect. One EMA study found that adolescents who engaged in more overall physical activity on average before a prompt reported more positive affect on average (Smith, Haedt-Matt, et al., 2020). However, several other EMA studies found no between-person association between average levels of MVPA before a prompt and positive affect in samples of children and adolescents (Dunton et al., 2014; Smith, Mason, et al., 2020; Wen et al., 2018). Additionally, Kühnhausen et al. (2013) found no between-person association between the percentage of the day participants spent in moderate or vigorous-intensity physical activity on average and valence in a sample of primary school-aged children.

There have also been mixed findings from EMA studies examining the between-person association between physical activity and incidental negative affect. Results from multiple studies showed that older children and adolescents who participated in more MVPA on average before a prompt reported less negative affect on average (Dunton et al., 2014; Smith, Mason, et al., 2020). However, multiple EMA studies also found no between-person association between average levels of MVPA before a prompt and negative affect in adolescents (Cushing et al., 2018; Smith, Haedt-Matt, et al., 2020; Smith, Mason, et al., 2020; Wen et al., 2018). Additionally, in another EMA study, average levels of overall moderate- or vigorous-intensity physical activity were not related to average levels of unpleasant affect in a sample of primary school-aged children (Kühnhausen et al., 2013). Similarly, daily diary studies found no between-person association between average daily MVPA with average negative mood in young adults (Haas et al., 2017), or average daily steps and average negative affect in children with symptoms of attention deficit hyperactivity disorder (Gawrilow et al., 2013).

Considering arousal, multiple EMA studies have found no significant between-person association between MVPA and energetic arousal (Dunton et al., 2014; Kühnhausen et al., 2013). Additionally, results from a daily diary study found no significant between-person association between average daily MVPA and average tense arousal in a sample of young adults (Haas et al., 2017).

Although there are mixed findings from EMA and daily diary studies regarding the between-person associations between MVPA and overall physical activity with incidental affect, there is a more consistent association when considering leisure-time physical activity. For example, results from daily diary studies have found that there was a positive between-person association between average daily self-reported leisure-time physical activity and average reported positive affect, and an inverse between-person relationship with average reported negative affect in a samples of year university students (Flueckiger et al., 2014; Hyde et al., 2011). However, no EMA or daily diary studies have examined whether the between-person association between physical activity and incidental affect differ between distinct domains of physical activity in adolescents. Although, a large cross-sectional study examined the association between leisure-time physical activity and active travel with incidental positive and negative affect (White, Parker, et al., 2018). The authors found that self-reported leisure-time physical activity was positively correlated with incidental positive affect and negatively correlated with incidental negative affect. In contrast, self-reported active travel was not correlated with incidental positive or negative affect. Yet, results also showed that neither device measured leisure-time physical activity or active travel were correlated with incidental positive affect and both were negatively correlated with incidental negative affect. Nevertheless, the authors concluded that leisure-time physical activity was a stronger predictor of incidental affect in adolescents than active travel. These results highlight that it may be important for young people to engage in more leisure-time physical activity to experience more favourable incidental affective states.

Considering satisfaction with life, to the author's knowledge, there have been no daily diary or EMA studies that have examined the between-person association between physical activity and satisfaction with life in adolescents. However, there have been multiple diary studies which have examined the between-person association between average daily physical activity and satisfaction with life in young adults. Most diary studies have found that average daily levels of self-reported leisure-time physical activity, self-reported overall physical activity, and device measured physical activity did not have a significant between-person association with daily satisfaction with life in young adults (Maher et al., 2014; Maher et al., 2013; Maher et al., 2015). However, Maher et al. (2015) found the between-person relationship between physical activity and satisfaction with life is age-dependent. Therefore, the association between daily physical activity and daily satisfaction with life may differ in adolescents compared to young adults. Additionally, although these studies did not find a significant between-person association between leisure-time physical activity and satisfaction with life, the association between physical activity and satisfaction with life may nevertheless be domain specific (White et al., 2017). For example, results from a cross-sectional study showed that there were stronger associations between physical activity and satisfaction with life for leisure-time physical activity than active travel, domestic, and work-related physical activity in a sample of university students (Pedišić et al., 2015). More research is needed to elucidate the between-person association between physical activity and components of subjective wellbeing and to determine whether the association between physical activity, incidental affect and satisfaction with life is domain specific, especially in adolescents.

Within-Person Association Between Daily Physical Activity and Subjective Wellbeing

Regarding the within-person association between daily physical activity and incidental affect, it has been found that young adults report more incidental positive remembered affect (Flueckiger et al., 2014; Flueckiger et al., 2017; Hyde et al., 2011) and positive evening affect (Haas et al., 2017) on days that they are more physically active than usual. However, these studies only measure affect on one occasion and therefore may be influenced by memory heuristics bias or not provide an accurate portrayal of affect experienced throughout the entire day. Additionally, there have been no studies to examine the within-person association between daily physical activity and incidental positive affect in adolescents. However, there is limited research examining the within-person relationship between physical activity and incidental negative affect in adolescents. Research in a population of adolescents diagnosed with attention deficit hyperactive disorder found that participants reported fewer feelings of depressed moods in the evening on days where they took more steps than usual (Gawrilow et al., 2013). Alternatively, a study involving German adolescents and emerging adults (12-26 years) found that participants did not report lower levels of depressed moods in the evenings on days that they were more active (Langguth et al., 2016). On the other hand, studies with young adults found that participants reported less negative remembered affect

(Flueckiger et al., 2017) and negative evening affect (Haas et al., 2017) on days that they were more physically active. Again, however, each of these studies only recorded affect on one occasion each day.

There have been fewer studies that have examined the within-person association between daily physical activity and average affect reported on multiple occasions through the day. In one of these studies, researchers found that participants reported more positive incidental valence on average throughout the day than they usually did on days they reported participating in more recreational physical activities, however, daily recreational physical activities were unrelated to daily incidental energetic or tense arousal (Schöndube et al., 2016). Additionally, in a sample of primary school aged children, Kühnhausen et al. (2013) found that neither the amount of time spent in device-measured moderate- or vigorous- intensity physical activity during a day had a within-person association with the level of incidental pleasantness, unpleasantness, activation, or deactivation reported throughout the day. However, to the author's knowledge, no studies have examined the within-person association between daily physical activity and average daily affect in adolescents,

In addition to daily affect, there are also no studies that have examined the within-person association between daily physical activity and satisfaction with life in adolescents. Promisingly, however, studies involving emerging adults (18-25 years) show a significant positive within-person association between self-reported daily leisure-time physical activity, daily self-reported overall MVPA, and daily device measured MVPA and satisfaction with life (Maher et al., 2014; Maher et al., 2013; Maher et al., 2015). These studies found that emerging adults reported being more satisfied with their life on days that they were more physically active than usual. More research is needed to determine whether, consistent with the within-person associations observed in emerging adults, daily levels of physical activity are associated with daily incidental affect and satisfaction with life in adolescents.

Affect as a Potential Mediator of the Association between Physical Activity and Satisfaction with Life

As well as limited research into the within-person association between daily physical activity and satisfaction with life, very little is known about the mechanisms which may explain this relationship. Researchers have hypothesized that affect (i.e., core affects, moods, emotions) mediates the association between physical activity and satisfaction with life (Elavsky et al., 2005; Lubans et al., 2016). This is consistent with empirical models, which show that affect is a distinct lower-order construct that influences cognitive evaluations of satisfaction with life (Blore et al., 2011; Tomyn & Cummins, 2011a).

It is hypothesised that participating in physical activity may be positively associated with satisfaction with life through improving affect in young people. Cross-sectional and longitudinal studies have shown that affect mediates the association between physical activity and satisfaction with life in young people and older adults (Elavsky et al., 2005; Joseph et al., 2014). A recent study also showed that remembered positive affect during exercise, but not remembered negative affect, mediated the positive association between exercise frequency and satisfaction with life in a sample of regular exercisers (Rodrigues et al., 2021). However, these studies only surveyed participants on one or two occasions and therefore could not determine whether affect mediated the association between physical activity and satisfaction with life on a day-today basis. Despite this, there is some research which shows that daily perceptions of physical and mental health may partially mediate the within-person association between daily self-reported leisure-time physical activity and satisfaction with life in adults (Maher et al., 2015). Additionally, in a daily diary study of college students, researchers found that daily positive and negative affect explained 100 percent of the within-person variance in daily perceptions of satisfaction with life (Jayawickreme et al., 2017b). Taken together, this indicates that there is potential for affect to mediate the within-person association between daily physical activity and satisfaction with life. However, to the author's knowledge, no studies have examined whether affect mediates the within-person or between-person association between physical activity and satisfaction with life in adolescents.

Thesis Aims, Research Questions, and Hypotheses

The overarching objective of this thesis is to investigate the mechanisms that may elucidate the association between physical activity and components of wellbeing in adolescents' daily lives. To achieve this overarching objective, this thesis has four aims: 1) determine to what extent the within-person and between-person association between MVPA and affect differs between distinct domains of physical activity (Chapter 3).

2) determine the extent to which the physical environment and social context influence the within-person association between MVPA and affect during physical activity in adolescents' daily lives (Chapter 4).

3) qualitatively investigate factors that adolescents perceive to lead to experiencing more positive affect while physically active (Chapter 5).

4) determine to what extent daily physical activity is associated with daily satisfaction with life and incidental affect, and whether the relationship between physical activity and satisfaction with life is mediated by incidental affect (Chapter 6).

The following research questions will be answered, and hypotheses tested for each of these research aims.

Aim 1: Determine to what extent the within-person and between-person association between MVPA and affect differs between distinct domains of physical activity.

Research questions and hypotheses

Q1. To what extent does the within-person association between MVPA and valence, energetic arousal, and tense arousal differ between recreational physical activity, active travel, and household physical activity?

> H1. Recreational physical activity will have a stronger positive within-person association with valence and energetic arousal and a stronger negative within-person association with tense arousal during physical activity than active travel and household physical activity.

Q2. To what extent does the between-person association between MVPA, valence, energetic arousal and tense arousal differ between recreational physical activity, active travel, and household physical activity?

> H2. Recreational physical activity will have a stronger positive between-person association with valence and energetic arousal and a stronger negative between-person association with tense arousal than active travel and household physical activity.

Aim 2: Determine the extent to which the physical environment and social context influence the within-person association between physical activity and affect during physical activity in adolescents' daily lives.

Research questions and hypotheses

Q1. To what extent does being outdoors and with someone else have an additive effect on the within-person association between MVPA and valence, energetic arousal, and tense arousal during physical activity in adolescents' daily lives?

> H1. Being outdoors will have a positive within-person association with valence and energetic arousal and an inverse within-person association with tense arousal, independent of levels of MVPA.
>
> H2. Being with someone else will have a positive within-person association with valence and energetic arousal and an inverse within-person association with tense arousal, independent of levels of MVPA.

Q2. To what extent do the physical environment and social context moderate the within-person association between physical activity and valence, energetic arousal and tense during physical activity arousal in adolescent's daily life?

> H3. The within-person association between MVPA and valence, energetic arousal and tense arousal during physical activity will be more favourable when participants are outdoors.
>
> H4. The within-person association between MVPA and valence, energetic arousal and tense arousal during physical activity will be more favourable when participants are with someone else.

Aim 3: Qualitatively investigate factors that adolescents perceive lead to experiencing more favourable affect while physically active.

Research questions

Q1. What factors do adolescents perceive lead to experiencing more positive valence, more energetic arousal, and less tense arousal while physically active?

Aim 4: Determine to what extent daily physical activity is associated with daily satisfaction with life and incidental affect, and whether the relationship between physical activity and satisfaction with life is mediated by incidental affect.

Research questions and hypotheses

Q1. To what extent is daily physical activity related to daily satisfaction with life and incidental affect?

H1. Adolescents will be more satisfied with their life on days when they are more physically active than usual.

H2. Adolescents will experience more positive incidental affect on days when they are more physically active than usual.

H3. Adolescents who are more physically active than others on average will be more satisfied with their life on average.

H4. Adolescents who are more physically active than others on average will experience more positive incidental affect on average.

Q2. To what extent does incidental affect mediate the association between physical activity and satisfaction with life?

H5. Incidental affect will mediate the within-person association between daily physical activity and satisfaction with life.

H6. Incidental affect will mediate the between-person association between average daily physical activity and average satisfaction with life.

Chapter 3: Domain-Specific Association between Physical Activity and Affect in Adolescents' Daily Lives

This chapter has been adapted from:

Bourke M., Hilland, T. A., & Craike, M. (2021). Domain specific association between physical activity and affect in adolescents' daily lives: an ecological momentary assessment study. *Psychology & Health.* https://doi.org/10.1080/08870446.2021.1965603

Introduction

As discussed in the preceding literature review, there have been mixed findings from EMA studies regarding the within-person association between physical activity and integral affect in adolescents' daily lives. Previous studies consistently reported a positive within-person association between MVPA and positive affect (Cushing et al., 2017; Dunton et al., 2014; Smith, Haedt-Matt, et al., 2020; Wen et al., 2018) and energetic arousal (Cushing et al., 2017; Dunton et al., 2014; Koch et al., 2020). However, studies have consistently found no within-person association between MVPA and negative affect (Cushing et al., 2017; Dunton et al., 2014; Smith, Haedt-Matt, et al., 2020; Smith, Mason, et al., 2020; Wen et al., 2018). There have also been mixed findings regarding the between-person association between MVPA and incidental affect. For example, Dunton et al. (2014) found that adolescents who participated in greater levels of MVPA on average reported less negative affect on average. However, they also found no between-person association between MVPA and positive affect or feelings of energy. Results from another EMA study found that the between-person association between MVPA and positive and negative affect was not significant in a sample of older children (Wen et al., 2018). Other researchers have found that vigorous-intensity physical activity, but not moderate-intensity physical activity has a positive cross-sectional association with positive affect and an inverse association with negative affect in adolescents (Costigan et al., 2019).

Given the mixed findings on the within- and between-person association between MVPA and affect, it is important to examine factors that influence this relationship. One potential factor that may explain differences in the association between MVPA and affect is the domain of life in which the physical activity occurs (Lubans et al., 2016; White et al., 2017). Young people may participate in several different domains of MVPA, including recreation, active travel, as part of the school curriculum (e.g., Physical Education), at home (e.g., while completing household chores or gardening), or as part of their employment.

There have been some studies which have examined the domain-specific relationship between physical activity and affect in young people. A qualitative study showed that adolescents perceived positive affect to be associated with physical activity during leisure-time physical activity more than active travel to school or physical activity during Physical Education (White, Olson, et al., 2018). Results from a cross-sectional study found that leisure-time MVPA was a stronger predictor of affect than MVPA from active travel in a sample of secondary school students (White, Parker, et al., 2018).

There have also been some recent studies in which researchers have examined the within-person association between different types of physical activity and affect in young people. Multiple EMA studies have found that the within-person association between physical activity and affect differs based on different physical activity types (e.g., incidental physical activity, exercise, sports) (Koch et al., 2020; Reichert et al., 2017). However, these studies did not find consistent evidence to suggest that exercise and sports had a more positive association with valence, energetic arousal and tense arousal than incidental physical activity. However, the authors of these studies included all non-exercise activity as incidental physical activity. They, therefore, did not compare distinct domains of MVPA such as household physical activity and active travel. In another study, researchers examined whether engaging in MVPA during leisure-time or while at work moderated the association between physical activity and affect in a sample of young adults (Kanning, 2013). Although they found that physical activity and being in leisure-time were independently related to valence, energetic arousal and tense arousal, they found that the being in leisure-time did not moderate the association between physical activity and affect. Again, however, this study did not compare distinct domains of physical activity.

While research suggests that the within-person and between-person association between MVPA and affect may differ for different types of physical activity, to the author’s knowledge, no researchers have examined both the within-person and between-person associations between domain-specific MVPA and affect in adolescents' daily lives. Therefore, this study aims to determine to what extent the within-person and between-person association between physical activity and affect differs between distinct domains of physical activity. To achieve this aim this study set out to answer the following research questions: 1) To what extent does the within-person association between MVPA and valence, energetic arousal, and tense arousal differ between recreational physical activity, active travel, and household physical activity? 2) To what extent does the between-person association between MVPA, valence, energetic arousal and tense arousal differ between recreational physical activity, active travel, and household physical activity? It is hypothesized that recreational physical activity will have a stronger positive within-person and between-person association with valence and energetic arousal and a stronger negative within-person and between-person association with tense arousal than active travel and household physical activity.

Methods

Participants

Adolescents were recruited between July 2019 and March 2020 in Melbourne, Australia. Adolescents were recruited through several methods, including advertisements placed on Facebook (Appendix B) and word of mouth. Adolescents were eligible to participate if they were between the ages of 13-17 years, they lived in an urban or suburban area of Melbourne, and they had a mobile phone with access to the internet. All participants and a parent or legal guardian were given written and verbal information about the study procedures before agreeing to participate in the study. Participants were told that the purpose of the study was to examine the relationship between physical activity and wellbeing in young people but were not made aware of the specific study aims. Written informed assent was sought from each participant in addition to written parental consent (Appendix C). The study procedures were approved by Victoria University Human Research Ethics Committee (Appendix D).

Procedures

Data were collected using EMA, using participants' mobile phones. Participants received a text message from an automated text messaging service (SMS Broadcast, Melbourne, Australia, https://www.smsbroadcast.com.au/). Each text message contained a link to a brief online questionnaire (Qualtrics, Provo, UT) and a four-digit ID number, which participants were asked to enter at the beginning of each questionnaire so that their responses could be linked. Each questionnaire took approximately 1-2 minutes to complete. Participants were asked to follow the link in the text message and complete the questionnaire as soon as possible upon receiving the text message. They were given 30-minutes to open the link to the questionnaire at each given prompt from the time that they received it, after which time responses were considered invalid and excluded. No reminder texts were sent after the initial text message.

Data collection occurred over four days (Thursday-Sunday). Prompts were sent between 7:45 am and 8:30 pm. Each day was broken into 90-minute windows and prompts were sent at least 45-minutes after the previous prompt to ensure that EMA prompts were spread over the entire day. Given that the use of mobile phones is banned during school hours in the local jurisdiction, no prompts were sent between 8:45 am and 3:15 pm on weekdays to ensure that participants would not receive any prompts during school times. On weekdays, participants were prompted five times (1x morning, 2x afternoon, 2x evening), and on weekend days, they were prompted nine times (3x morning, 4x afternoon, 2x evening). Each participant was compensated $30 for their participation in the study.

Measures

An overview of self-reported measures participants responded to when completing each EMA prompt can be seen in Appendix E.

Moderate-To-Vigorous Physical Activity

Minutes of MVPA were measured using the ActiGraph GT3X+ (ActiGraph LLC, Pensacola, FL, USA). The device was positioned on top of participants' dominant wrist attached by a nylon strap. The researcher demonstrated how to properly wear the device with all participants before beginning the data collection period. Participants were instructed to wear the accelerometer at all times except when they were sleeping, during water-based activities, when participating in activities where wearing accessories was prohibited, or during activities where there was a risk that wearing the accelerometer could result in participant injury or damage to the device. Participants were sent a text message at 7:30 each morning reminding them to wear their accelerometer.

Accelerometers were initialized to sample at a frequency of 30Hz, and the low-frequency extension was turned on. Data were filtered through ActiGraph's band-limited digital filter with a frequency range of 0.25 Hz to exclude gravitational components and 2.5 Hz to exclude non-normal human motion. Raw movement data were downloaded from the vertical axis in 5-second epochs using Actilife version 6.12.1 (ActiGraph LLC, Pensacola, FL, USA). Data were classified according to the MVPA cut point of greater than 4320 counts per minute (Crouter et al., 2015).

For this study, MVPA was operationalized as the minutes of MVPA in the 15-minutes immediately before participants completed an EMA prompt. Authors have shown that the amount of device-measured physical activity does not differ in the 15-minutes before and after an EMA prompt in young people (Dunton, Liao, Intille, Spruijt-Metz, et al., 2011), indicating that employing a window of 15-minutes before an EMA prompt captures responses during physical activities, rather than following activities. MVPA data were considered valid if accelerometers were worn for at least half of the 15 minutes before completing an EMA prompt. Non-wear time was defined using well-established guidelines as any interval of at least 60 consecutive minutes with zero counts, allowing for spikes for up to two minutes in activity counts between 0-100 counts per minute (Troiano et al., 2008). MVPA data from accelerometers were matched with EMA prompts using electronic timestamps.

Activity Type

To determine the type of activity in which participants were engaged, participants reported their current activity by answering the question, "What were you doing right before you opened this prompt?" Response options were adapted from Dunton, Liao, Intille, Spruijt-Metz, et al. (2011) and included: physical activity or exercise, reading or doing homework, using social media, playing computer/video games, watching TV or a movie, eating a meal, housework or chores (recorded as household physical activity), or other. If participants selected 'other', they were asked to describe the activity they were doing in a text box. If participants reported physical activity or exercise, they were asked to indicate what sort of physical activity or exercise they were doing. Response options included recreational physical activities (i.e.

walking for fun or exercise, including on a treadmill; riding my bike, scooter or skateboard for fun or exercise, including on a stationary bike; running, including on a treadmill; playing a sport or physically active game; dancing; gym or group fitness class; swimming; gymnastics or cheerleading; yoga or pilates), and active transport (i.e. walking to get from place to place; riding my bike, scooter or skateboard to get from place to place). Participants could also select 'other' and describe the physical activity or exercise that they were participating in in a text box. Participants' written responses were coded as recreational physical activity, active travel, or household physical activity where applicable.

Core Affect

Participants' core affect at the time of each prompt was measured using a short validated scale explicitly developed for ambulatory monitoring of core affect in everyday life (Wilhelm & Schoebi, 2007). The scale measures three dimensions of core affect: valence, energetic arousal, and tense arousal. Participants responded to the prompt "At this moment I feel" on six bipolar scales, two for each dimension of core affect, on a 7-point sliding scale. Valence was measured using scales with anchors of discontent-content and unwell-well; energetic arousal was measured using scales with anchors of tired-awake and unenergetic-energetic; tense arousal was measured using scales with anchors of calm-agitated and relaxed-tense. Each anchor was preceded with the adverb "very". Responses were indicated by moving the slider to the left or right of the scale from its initial position at the center of the scale. Participants could leave the slider in the middle of the scale by tapping the slider but not moving it. When participants moved the slider, the corresponding score (from 1-7) was displayed next to the scale. A score between 2-14 was calculated for each affective dimension at each prompt, with a higher score indicating more positive valence, and greater energetic arousal and tense arousal. The within-person reliability of the valence, energetic arousal, and tense arousal subscales in the current study was 0.35, 0.68, an 0.71, respectively. The between-person reliability of the subscales was 0.77, 0.90, and 0.94, respectively. Although the within-person reliabilities are sub-optimal based on traditional guidelines (Shrout, 1998), especially for valence, a relaxed criteria for acceptable reliability may be applied at the within-person level for scales with few items (Nezlek, 2017).

Time Of Day and Day of Week

Based on electronic time stamps from Qualtrics, the time each EMA prompt was completed was coded according to the day of week (0=weekday, 1=weekend) and time of day (1=morning [7:30am-11:59am], 2=afternoon [12:00pm-5:59pm], 3=evening [6:00pm-8:30pm]).

Demographics

Before the data collection period, participants reported their age, sex, and postcode. Participants' postcodes were used to determine the Socio-Economic Indexes for Areas (SEIFA) (Australian Bureau of Statistics, 2016), an area level indicator of socio-economic status. The SEIFA broadly defines the socio-economic advantage and disadvantage of an area in terms of people's access to material and social resources. The SEIFA is standardized to have a mean of 1000 and a standard deviation of 100, with a higher score indicating more socio-economic advantage and less socio-economic disadvantage.

Data Preparation

Domain-specific minutes of MVPA in the 15-minutes before an EMA prompt were recorded based on the type of activity participants reported right before completing the prompt and the levels of MVPA measured by their accelerometer. For example, if a participant reported participating in recreational physical activities, and their accelerometer measured 5 minutes of MVPA in the 15 minutes before an EMA prompt, it was recorded that participants participated in 5 minutes of recreational MVPA. If participants reported not participating in physical activity or doing housework or chores immediately before completing the prompt, zero minutes of MVPA were recorded for all domains of MVPA at that prompt. For each domain of MVPA, within-subject effects were disaggregated from between-subject effects by centering the level of MVPA in the 15-minutes before a given prompt around the participant's mean level of MVPA for each domain ($e.g. Recreational\ MVPA_{ti} - \overline{Recreational\ MVPA_i}$). Doing so ensures that only within-person differences, not between-person differences, are included in the lower level of the model (Nezlek, 2012). Additionally, between-subject effects were calculated by subtracting each individual's average level of MVPA from the grand mean for each domain ($e.g.\ \overline{Recreational\ MVPA_i} - \overline{Recreational\ MVPA}$). As suggested by Nezlek (2012), the dummy codes for physical environment and social context were entered uncentered to aid interpretation.

Data Analysis

All data analysis was conducted using SPSS version 25 (IBM). First, descriptive statistics were calculated for all study variables. Next, compliance was calculated for each participant. An independent sample t-test was used to estimate whether compliance differed between sexes. Linear regression was used to estimate whether compliance was associated with participants' age or SES. Additionally, differences in compliance rates were calculated based on the day of the week (weekday or weekend), and time of day (morning, afternoon or evening) using multilevel linear models.

A series of multilevel models were estimated to examine relationships with affective outcomes. Multilevel models account for the nested structure of data; which for EMA is prompts nested within participants (Nezlek, 2012). Models were run separately for each core affect outcome (i.e., valence, energetic arousal, tense arousal). First unconditional models were run for each outcome variable with a random intercept and no predictor variables to calculate the intraclass correlation coefficient (ICC) to determine how much of the variance is explained at the between-person and within-person levels.

Next, to test domain-specific associations between MVPA and each of the core affect outcomes, a series of multilevel models were estimated. All models were entered with the predictors, sex, age, SES, day of the week, time of the day, recreational MVPA, MVPA from active travel, and household MVPA. All models were initially estimated with a random intercept and a random effect for all within-person variables. All non-significant ($p > .05$) random effects were removed so that the final models were run with only significant random effects and a random intercept. The equation for the multilevel models is as follows:

Level 1

$$Affect_{ti} = \beta_{00} + \beta_{10}(Day\ of\ week_{ti}) + \beta_{20}(Time\ of\ day_{ti})$$
$$+ \beta_{30}(WP\ RecreationalMVPA_{ti}) + \beta_{40}(WP\ Active\ Travel\ MVPA_{ti})$$
$$+ \beta_{50}(WP\ Household\ MVPAPA_{ti}) + r_{ti}$$

Level 2

$$\beta_{00} = \gamma_{00} + \gamma_{01}\ (Age_i) + \gamma_{02}\ (Sex_i) + \gamma_{03}\ (SES_i)$$
$$+ \gamma_{04}\ (BP\ Recreational\ MVPA_i) + \gamma_{05}\ (BP\ Active\ Travel\ MVPA_i)$$
$$+ \gamma_{06}\ (BP\ Household\ MVPA_i) + \mu_{0i}$$

$$\beta_{(1-5)0} = \gamma_{(1-5)0} + \mu_{(1-5)i}$$

where level-1 estimates the within person-effects on core affective state for each participant (subscript i) at each prompt (subscript t). Beta-coefficients were estimated for the average intercept across all participants (β_{00}), the within-person effects of the day of the week (β_{10}), time of day (β_{20}), recreational MVPA (β_{30}), MVPA from active travel (β_{40}), and household MVPA (β_{50}). Level-2 estimates the between-person effects of age (γ_{01}), sex (γ_{02}), SES (γ_{03}), average levels of recreational MVPA (γ_{04}), average levels of MVPA from active travel (γ_{05}) and average levels of household MVPA (γ_{06}). The random intercept is represented as μ_{0i} and the random slopes for within-person effects (when significant variance in slopes was observed between participants) are represented as $\mu_{(1-5)i}$.

Main analyses were conducted with all participants regardless of compliance. A sensitivity analysis was also conducted which only included participants who completed at least 50% of the EMA prompts (n = 91). Results from the sensitivity analysis are presented in Appendix F.

Results

Descriptive Statistics

Overall, 125 participants were recruited into the study. Of these, 53.6% were male, and the average age of participants was 14.65 years (SD = 1.44). The average SEIFA score for the participants' postcodes was 1030.57 (SD = 54.20), indicating that participants lived in relatively affluent areas.

At each prompt, participants reported an average level of valence of 11.21 (SD = 2.13), energetic arousal of 9.20 (SD = 3.01), and tense arousal of 4.84 (SD = 2.29). The ICC for valence, energetic arousal and tense arousal were .49, .34 and .40, respectively, indicating that 51%, 66% and 60% of the variance in each respective outcome was explained within individuals.

Participants reported participating in recreational physical activities during 10.5% (n = 172) of prompts, active travel during 4.1% (n = 67) of prompts and household physical activities during 6.0% (n = 98) of prompts. The most reported type of recreational physical activities included playing a sport or physically active game (50.7%), walking for fun or exercise (17.1%), gym or group fitness class (9.0%), and running (6.2%). For active travel, participants reported walking to get from place to place on 90.4% of occasions and riding a bike scooter or skateboard to get from place to place on the remaining 9.6% of occasions. The average activity intensity in the 15 minutes before an EMA prompt when participants reported participating in recreational physical activities, active travel, and household physical activities was 2.59 METs, 2.46 METs, and 2.34 METs, respectively.

Compliance

There were unknown technical issues for three participants, which meant that they did not receive any text messages during the study period. Additionally, a single participant was non-compliant and did not complete any of the EMA prompts. There was also an initialization error with the accelerometers for two participants, meaning that their accelerometer data was unavailable. Therefore, data for a total of 119 participants were included in the analyses (Figure 3.1).

The average compliance rate was 60.1% (SD = 20.7%, range 7-96%). Female participants had a significantly greater compliance rate than male participants, mean difference (MD) = 11.5%, 95%CI = [3.7%, 18.8%], $t(117) = 3.16$, $p = .002$. There was also a negative relationship between age and compliance; every year older was associated with a 2.8% lower compliance rate ($p = .037$). Socio-economic status was not related to the compliance rate.

Participants had a greater compliance rate for prompts sent on weekdays compared to prompts sent on weekends, MD = 14.6%, 95% CI = [10.8%, 18.5%], $F(1,119) = 57.43$, $p < .001$. There was also a significant difference in compliance rates between prompts sent in the morning, afternoon, and evening, $F(2,238) = 15.51$ $p < .001$. Post hoc analysis using simple comparisons shows that there was significantly lower compliance in the morning than the afternoon, MD = -10.8%, 95%CI = [-14.9%, -6.8%], $p<.001$, and significantly lower compliance in the morning compared to the evening, MD = -8.5%, 95%CI = [-12.5%, -4.5%], $p<.001$. There was no difference in compliance between prompts sent in the afternoon and prompts sent in the evening.

Of the 2,017 prompts completed by participants, an average of 16.95 prompts per participant, 81.1% of prompts could be matched with valid accelerometer data. Therefore, 1,636 prompts from 119 participants were included in the analyses (Figure 3.1).

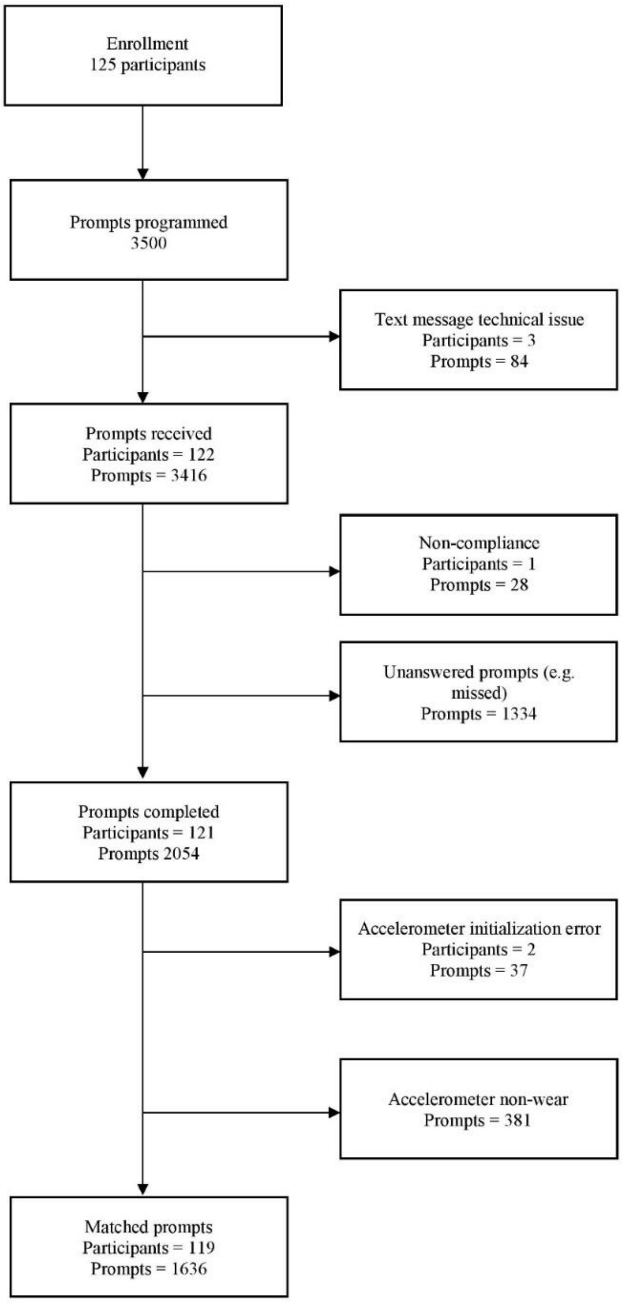

Figure 3.1 Participant and data availability flow chart

Domain-Specific Association Between MVPA and Valence

Results from the multilevel model on valence are displayed in Table 3.1. There was no significant within-person association between any domain of MVPA and valence. However, there was a significant positive between-person association between recreational MVPA and valence. Participants who participated in greater levels of recreational MVPA on average reported more positive valence. There were no between-person associations between MVPA from active travel or household MVPA and valence.

Domain-Specific Association Between MVPA and Energetic Arousal

Results from the multilevel model on energetic arousal are displayed in Table 3.1. There was a positive within-person association between recreational MVPA and energetic arousal. Participants reported greater energetic arousal when they participated in greater levels of recreational MVPA than usual. There were no within-person associations between MVPA from active travel or household MVPA and energetic arousal. Results also showed that there was a positive between-person association between recreational MVPA and energetic arousal. Participants who participated in greater levels of recreational MVPA on average reported greater levels of energetic arousal. There was no between-person association between MVPA from active travel or household MVPA and energetic arousal.

Domain-Specific Association Between MVPA and Tense Arousal

Results from the multilevel model on tense arousal are displayed in Table 3.1. There was a positive within-person association between recreational MVPA and tense arousal such that participants reported being tenser when they participated in more recreational MVPA than usual. There was no within-person association between MVPA from active travel or household MVPA and tense arousal. Results also showed a between-person association between recreational MVPA and tense arousal, however, in the opposite direction than the within-person association. Participants who participated in greater levels of recreational MVPA on average reported being less tense on average. There was no between-person association between MVPA from active travel or household MVPA and tense arousal. Results from the sensitivity analysis are displayed in Appendix F. Results from the sensitivity analysis were consistent in terms of direction and magnitude as those of the main analysis.

Table 3.1 Results from the multilevel models predicting valence, energetic arousal and tense arousal

	Valence			***Energetic Arousal***			***Tense arousal***		
	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Fixed effects, model parameter									
Intercept, β_{00}	**12.09**	**2.79**	**<.001**	**10.97**	**3.40**	**.002**	**7.19**	**2.65**	**.001**
Sex (Female referent), γ_{01}	0.40	0.29	.163	0.64	0.35	.069	-0.39	0.27	.154
Age, γ_{02}	0.01	0.10	.913	0.09	0.12	.481	-0.10	0.10	.311
SES, γ_{03}	-0.00	0.00	.583	-0.00	0.00	.280	-0.00	0.00	.825
Day of week (Weekend referent), β_{10}	**-0.30**	**0.13**	**.019**	**-0.63**	**0.17**	**<.001**	0.15	0.14	.279
Time of day (Morning referent), β_{20}									
Afternoon	**0.28**	**0.10**	**.004**	**0.67**	**0.18**	**<.001**	-0.18	0.12	.125
Evening	**0.35**	**0.10**	**.001**	0.18	0.18	.329	**-0.32**	**0.12**	**.010**
Recreational MVPA (within) β_{30}	0.01	0.02	.553	**0.18**	**0.04**	**<.001**	**0.06**	**0.03**	**.037**
Recreational MVPA (between), γ_{04}	**0.62**	**0.28**	**.030**	**0.95**	**0.34**	**.007**	**-0.65**	**0.27**	**.017**
Active travel (within), β_{40}	0.04	0.04	.300	0.10	0.06	.115	-0.02	0.05	.611
Active travel (between), γ_{05}	-0.34	0.33	.293	-0.18	0.41	.661	0.24	0.32	.456
Household MVPA (within), β_{50}	0.03	0.04	.448	0.09	0.06	.130	-0.01	0.04	.822
Household MVPA (between), γ_{06}	-0.57	0.48	.239	-0.16	0.59	.783	0.82	0.46	.078
Random effects									
Residual, r_{ti}	**2.02**	**0.08**	**<.001**	**4.67**	**0.19**	**<.001**	**2.90**	**0.11**	**<.001**
Intercept, μ_{0i}	**1.73**	**0.30**	**<.001**	**2.25**	**0.44**	**<.001**	**1.39**	**0.27**	**<.001**
Day of the week, μ_{1i}	**0.51**	**0.12**	**<.001**	**0.79**	**0.21**	**<.001**	**0.61**	**0.14**	**<.001**
Time of day, μ_{2i}	-	-	-	**0.39**	**0.14**	**.007**	-	-	-

SE = Standard error, bolded significant at p < .05

Discussion

The purpose of this study was to examine the associations between recreational MVPA, MVPA from active travel, and household MVPA on valence, energetic arousal, and tense arousal. Results showed that the within-person and between-person association between MVPA and core affect may differ depending upon which domain of life the physical activity occurs. Consistent with the study hypothesis, findings suggest that participating in recreational MVPA may have the strongest favourable between-person association with all components of core affect. Adolescents who participated in more recreational MVPA than others felt more pleasant and energetic, and less tense than adolescents who participate in less recreational physical activity on average. However, neither active travel nor household MVPA had significant between-person associations with any of the affective outcomes. Although results showed a significant between-person association between recreational MVPA and valence, in opposition of the study hypothesis, findings indicate that none of the domains of MVPA examined in the current study had a within-person association with valence. However, results did show that participating in recreational MVPA had a significant positive within-person association with energetic arousal, but also a significant positive within-person association with tense arousal. Neither active travel nor household MVPA had a significant within-person association with energetic arousal or tense arousal.

The findings from the current study add to previous qualitative research, which showed that more young people perceived positive affect to be associated with participation in recreational physical activities than active travel or physical activity during Physical Education (White, Olson, et al., 2018). Similarly, the results from the current study are consistent with results from cross-sectional research, which showed that self-reported recreational MVPA was positively correlated with positive affect and negatively correlated with negative affect in adolescents, whereas self-reported active travel was not correlated with either positive or negative affect (White, Parker, et al., 2018). However, unlike previous studies in which researchers asked participants to retrospectively report affect, which may be based on semantic knowledge and distorted by memory heuristics bias (Robinson & Clore, 2002; Trull & Ebner-Priemer, 2013), the current study repeatedly measured momentary affect which can account for time-sensitive ebbs and flows in affect (Trull et al., 2015). Therefore, the current study may provide a more accurate reflection of participants' affect during daily life.

These results highlight the importance of encouraging young people to participate in recreational MVPA to promote positive affect. Participating in other domains of physical activity, including active travel and household physical activity, are unlikely to have the same affective benefits in young people. This may be because recreational physical activities are perceived as more intrinsically motivated, allow for mastery of skills, and are generally more social than physical activity completed in other domains, which may all lead to more positive affective outcomes (Ryan et al., 2009; White, Olson, et al., 2018).

Given that affect has been hypothesized as a mechanism that explains the mental health benefits of participating in MVPA (Lubans et al., 2016), results of this study suggest that it may be particularly important to encourage participation in recreational physical activities to promote mental health in young people. The findings that only recreational physical activities had a between-person association with affect in the current study adds to meta-analytic evidence that participation in recreational physical activities has a stronger positive association with mental health and a stronger negative association with mental ill-health than participation in household physical activity, Physical Education, and school sport (White et al., 2017).

Consistent with the between-person association, the present study showed that neither active travel nor household MVPA had a within-person association with valence, energetic arousal or tense arousal. However, the results regarding the acute within-person effects of participating in recreational MVPA on affect differed from the between-person associations. Participating in more recreational MVPA than usual was not associated with more positive valence, but was positively related to energetic arousal and tense arousal. Therefore, while adolescents who participate in more recreational MVPA than their peers feel more pleasant and less tense, the immediate effects appear less favourable, or even adverse when considering tense arousal.

The within-person associations observed in the current study differ from those found by authors of previous studies (Koch et al., 2020; Reichert et al., 2017). For example, Koch et al. (2020) found that incidental physical activity had a positive within-person association with valence. However, these authors defined incidental physical activity as all physical activity that occurred outside of exercise. Therefore, unlike the current study, which examined active travel and household MVPA specifically, the previous study included incidental physical activity that occurred during other potentially pleasurable behaviours, which may have been positively associated with affect. Additionally, contrary to the results from the current study, Koch et al. (2020) found that participating in sport was negatively associated with energetic arousal. Also in opposition to the results of the current study, Reichert et al. (2017) found that participating in greater levels of exercise than usual was associated with more positive valence and less tense arousal in a sample of young adults. However, both Koch et al. (2020) and Reichert et al. (2017) used daily reconstruction methods to identify bouts of participation in sport and exercise retrospectively and matched them to the closest corresponding report of affect following the bout of exercise. Therefore, unlike the current study, which examined the relationship between recreational MVPA and affect *during* physical activity, the authors of these previous studies examined the relationship between exercise and affect some time *after* physical activity. These contrasting findings are consistent with the propositions of the Dual-Mode Model that the relationship between physical activity and valence will be more positive following participation in physical activity than during physical activity (Ekkekakis et al., 2005), and research which has shown the inverse is true for energetic arousal (Ekkekakis et al., 2008). Given affect experienced during MVPA, but not following participation in MVPA, is associated with future participation in physical activity (Rhodes & Kates, 2015), further research is needed to understand factors that may enhance young people's affective experience during recreational MVPA.

A previous EMA study also showed that more autonomously motivated physical activities are associated with greater energetic and tense arousal during physical activity in young adults (Kanning et al., 2012). This may somewhat explain why only recreational MVPA had a positive within-person association with energetic arousal and tense arousal in the current study. However, it is also possible that positive within-person association between recreational MVPA and energetic and tense arousal in this study could also be explained by the greater intensity of recreational physical activities in the current study. Previous research has shown that ratings of energetic arousal may be sensitive to physical activity intensity in young people, such that higher intensities are related to greater arousal (Sheppard & Parfitt, 2008a). The current study showed that activity intensity was greatest when participants reported engaging in recreational physical activities. Additionally, commonly reported recreational physical activities in the present study included playing sport or a physically active game, gym or group fitness class, and running. The intensity of these activities was likely greater than the intensity of walking or cycling to get from place-to-place, and the intensity of everyday household physical activities (Butte et al., 2018).

This study adds to our understanding of the domain-specific association between MVPA and affect in adolescents. However, some limitations must be considered when interpreting the results. First, participants only reported participating in physical activities during 20.6% of completed EMA prompts. Although this reflects physical activity patterns in young people outside of school times, which are dominated by sedentary behaviours (Arundell et al., 2016), and is comparable to other studies (Koch et al., 2020; Reichert et al., 2017), it means that the estimates are based on a relatively small number of observations. This could potentially explain some of the null effect observed in our study. Using activity triggered or event contingent sampling may capture a higher proportion of physical activities. Another limitation of this study is that participants were asked to remove their accelerometer during water activities and activities where the accelerometer could be damaged or potentially cause injury. Therefore, participants may not have worn their accelerometer during all types of physical activities (e.g., swimming, contact sports), meaning that some bouts of physical activity were excluded from the analysis. Future studies could use diaries or logs to supplement accelerometer data. Alternatively, researchers might consider using thigh worn accelerometers that are more easily waterproofed and less obstructive during recreational physical activities.

Conclusion

This study aimed to determine to what extent the within-person and between-person association between physical activity and affect differs between distinct domains of physical activity. Results showed that adolescents who participated in higher levels of recreational MVPA on average experienced more positive valence, higher levels of energetic arousal and lower levels of tense arousal. However, engaging in more MVPA from active travel or household chores on average was not associated with any of the affective outcomes. This highlights the importance of encouraging young people to engage in recreational MVPA to promote their affective wellbeing. Results also showed that when adolescents engaged in more recreational MVPA than their usual level, they reported higher levels of energetic arousal, but also more tense arousal. No domains of MVPA had a within-person association with valence.

Chapter 4: Contextual Influences on The Within-Person Association Between Physical Activity and Affect in Adolescents

This chapter has been adapted from:

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Introduction

Given mixed findings regarding the acute within-person association between physical activity and affect in adolescents' daily lives reported in previous studies (Cushing et al., 2017; Dunton et al., 2014; Smith, Haedt-Matt, et al., 2020; Smith, Mason, et al., 2020; Wen et al., 2018), it is important to examine factors that may influence the relationship between physical activity and affect. Given that there is no archetypical MVPA behaviour or context, a range of individual and contextual factors may impact an individual's affective experience when physically active (Backhouse et al., 2007). As discussed in the literature review, some contextual factors that can influence the relationship between physical activity and affect include the physical environment and social context.

Considering the physical environment, evolutionists suggest that humans have an innate tendency to pay attention to, associate with, and respond positively to natural environments (Kellert & Wilson, 1993). As such, it is hypothesized that environments composed of natural elements will have psychologically restorative benefits, including stress reduction (Ulrich, 1983; Ulrich et al., 1991), and attention restoration (Kaplan, 1995). Furthermore, from an ecological dynamics perspective, natural environments may be positively associated with affect because they promote the participation in a wider range of physical activity behaviours and encourage more positive psychological responses that can promote wellbeing, compared to manufactured environments (Araújo et al., 2019; Yeh, Stone, Churchill, Wheat, et al., 2016).

Considering the social context, relatedness, a sense of connection and belonging, is one of the three basic psychological needs that the SDT suggests is essential to wellbeing (Ryan et al., 2009). Additionally, stress-buffering models propose that social interactions may influence psychological outcomes during stressful events by reducing the impact of stress (Cohen et al., 2000). Therefore, social interactions may provide individuals with information about coping with stress and increase their perceptions of self-esteem and personal control whilst being physically active (Cohen, 1988; Cohen et al., 2000).

There are several ways in which the benefits of physical activity are potentially enhanced or diminished by contextual factors (Shanahan et al., 2016). The context may have an additive effect when it has a positive association with affect independent of levels of MVPA, a sub-additive impact on affect when the context has a negative association with affect independent of levels of MVPA, or a synergistic effect where the context and levels of MVPA interact to determine affect (Shanahan et al., 2016).

Evidence suggests that there may be added benefits on affect from being physically active outdoors and with other people in daily life. A study involving children, which compared levels of positive and negative affect during self-reported

MVPA in daily life found significantly more positive affect during leisure-time MVPA when outdoors compared to someone else's house, and when in their front/backyard compared to indoors or at someone else's house (Dunton, Liao, Intille, Wolch, et al., 2011). Additionally, children reported significantly less negative affect during self-reported leisure-time MVPA when with friends or family compared to when alone (Dunton, Liao, Intille, Wolch, et al., 2011). A study involving adults has also shown that adults report more positive valence during self-reported bouts of walking in daily life when walking with others compared to walking alone (Boyle et al., 2020). However, this study showed no difference in valence reported by participants when walking inside compared to outside (Boyle et al., 2020). Although these studies demonstrated that there might be added benefits to being physically active outdoors or with someone else during daily life, they did not test whether the physical environment or social context interact with levels of MVPA to predict affect.

There is some evidence of an interaction effect between contextual factors and MVPA on affect in daily life in adults. For example, researchers have found that the physical environment moderated the association between self-reported physical activity and negative affect (Dunton et al., 2015). They found that there was an inverse association between being physically active and negative affect only when participants were active outdoors (Dunton et al., 2015). Considering the social context, researchers have found that the social context moderated the association between self-reported physical activity and positive affect (Dunton et al., 2015). They found that there was a positive within-person association between being active and positive affect only when adults were active with someone else. Additionally, Kanning and Hansen (2016) found that the social context moderated the association between overall levels of device-measured physical activity and tense arousal in older adults. They found that there was a stronger positive association between physical activity and tense arousal when alone. However, to the author's knowledge, no studies have examined whether there is an interaction effect between contextual influences and MVPA on affect in adolescents.

Therefore, the current study aims to determine the extent to which the physical environment and social context influence the within-person association between physical activity and affect in adolescents' daily lives. To achieve this aim, the study will answer the following research questions: 1) To what extent does being outdoors and with someone else have an additive effect on the within-person association between MVPA and valence, energetic arousal, and tense arousal in adolescents' daily lives? 2) To what extent do the physical environment and social context moderate the within-person association between physical activity and valence, energetic arousal and tense arousal in adolescent's daily life? It is hypothesized that being outdoors and being with someone else will have a positive within-person association with valence and energetic arousal and an inverse within-person association with tense arousal, independent of levels of MVPA. Additionally, it is hypothesized that the within-person association between MVPA and valence, energetic arousal and tense arousal will be more favourable when participants are outside and with someone else.

Methods

Participants

Participant recruitment is described in detail in Chapter 3. Briefly, participants were adolescents aged 13-17 years, living in an urban or suburban area of Melbourne with a mobile phone with access to the internet. Written informed assent was sought from each participant in addition to written parental consent (Appendix C). The study procedures were approved by Victoria University Human Research Ethics Committee (Appendix D).

Procedures

Data collection procedures are described in detail in Chapter 3. Briefly, data were collected over four days (Thursday-Sunday) using EMA by sending text messages with a link to an online questionnaire to participants' mobile phones. Participants were prompted between 5-9 times each day. Participants were asked to follow the link in the text message and complete the questionnaire as soon as possible upon receiving the text message. Participants were given 30-minutes to open the link to the questionnaire at each given prompt from the time they received it, after which time responses were considered invalid and excluded. No reminder texts were sent after the initial text message was sent for each prompt.

Measures

An overview of self-reported measures participants responded to when completing each EMA prompt can be seen in Appendix E.

Moderate-To-Vigorous Physical Activity

The measurement of MVPA is described in detail in Chapter 3. Briefly, levels of MPVA were measured using the ActiGraph GT3X+ (ActiGraph LLC, Pensacola, FL, USA). The device was positioned on top of the participants' dominant wrist. Data were classified according to the MVPA cut point for the ActiGraph GT3X+ placed on youth's dominant wrist of greater than 4320 counts per minute (Crouter et al., 2015). For this study, MVPA was defined as the overall level of device-measured MVPA in the 15-minutes immediately before participants completed an EMA prompt. In this study, 15-minute windows immediately before an EMA prompt with less than 50% wear time were excluded from the analyses. Non-wear time was defined using well-established guidelines as any interval of at least 60 consecutive minutes with zero counts allowing for spikes for up to two minutes in activity counts between 0-100 counts per minute (Troiano et al., 2008). MVPA data from accelerometers were matched with EMA prompts using electronic timestamps.

Core Affect

The measure of core affect is described in detail in Chapter 3. Briefly, participants' core affect at the time of each prompt was measured using a short scale developed specifically for ambulatory monitoring of core affect in everyday life (Wilhelm & Schoebi, 2007). Valence was measured using two items with anchors of discontent-content and unwell-well; energetic arousal was measured using two items with anchors of tired-awake and unenergetic-energetic; tense arousal was measured using two items with anchors of calm-agitated and relaxed-tense.

Physical Environment

Participants reported their current physical environment at the time of the prompt by answering the question, "Where are you right now?" Response options were adapted from Dunton, Liao, Intille, Spruijt-Metz, et al. (2011) and included: at home, outdoors, in a school classroom, at a shopping centre, at someone else's house, at a gym or recreation centre, in a motor vehicle, someplace else. If participants reported someplace else, they were asked to describe their current physical environment in a text box. If participants selected outdoors, their response was dummy coded as 1 = outdoors. If they selected any other option, their response was dummy coded 0 = indoors.

Social Context

Participants reported their current social context at the time of the prompt by answering the question, "Who are you with right now?" Response options were adapted from Salvy et al. (2007) and included: alone, friend/s, sibling/s, parent/s, another family member/s, stranger/s, someone else. If participants reported being with someone else, they were asked to describe the person they were within a text box. Participant's responses were then dummy coded 0 = alone and 1 = not alone.

Weather and Ambient Temperature

Two single items were used to assess the weather and temperature at each prompt and were adapted from Bejarano et al. (2019). For both items, participants were asked, "What is the weather like outside now?" Response options were raining, overcast clear; too hot, too cold, pleasant.

Time Of Day and Day of Week

Based on electronic time stamps from Qualtrics, the time each EMA prompt was completed was coded based on the day of week (0=weekday, 1=weekend) and time of day (1=morning [7:30am-11:59pm], 2=afternoon [12:00pm-5:59pm], 3=evening [6:00pm-8:30pm]).

Demographics

Participants reported their age, sex, and postcode. Postcode data was used to determine each participant's SEIFA (Australian Bureau of Statistics, 2016).

Data Preparation

As described in Chapter 3, the within-subject effects for device measured MVPA were disaggregated from between-subject effects by centering the level of MVPA in the 15-minutes before a given prompt around the participant's mean level of MVPA. As suggested by Nezlek (2012) all dummy codes were entered uncentered. Therefore, the intercept can be interpreted as the mean when all dummy codes are zero (i.e. when participants are alone and indoors) and the beta-coefficient can be interpreted as the mean difference when participants are outdoors or with someone else.

Data Analysis

All data analysis was conducted using SPSS version 25 (IBM). To answer each of the research questions a series of multilevel models were run. Multilevel models account for the nested structure of data, which in this study was prompts nested within participants, by estimating an error term for each level of the analysis (Nezlek, 2012). Models were run separately for each core affect outcome.

A series of multilevel models with direct and interaction effects were estimated for each core affect outcome to test the research hypotheses. First, models were run to include all direct effects to determine whether within-person MVPA, the physical environment and social context had independent associations with each outcome controlling for participant sex, age and SES, as well as the time of day, the day of week, and the weather conditions and ambient temperature at the time of the prompts. Next, interaction terms were calculated between MVPA and each contextual factor and were entered individually into the main effects model to test hypothesized moderating effects. All models were initially estimated with a random intercept and a random effect for within-person variables. All non-significant (p > .05) random effects were removed, so the final models were run with only significant random effects and a random intercept. The equation for the moderator models is as follows:

Level 1

$$\begin{aligned} Affect_{ti} = \beta_{00} + \ & \beta_{10}(Day\ of\ week_{ti}) + \ \beta_{20}(Time\ of\ day_{ti}) + \ \beta_{30}(Weather_{ti}) \\ & + \beta_{40}(Temperature_{ti}) + +\beta_{50}(Physical\ environment_{ti}) \\ & + \beta_{60}(Social\ context_{ti}) + \beta_{70}(MVPA_{ti}) \\ & + \beta_{80}(MVPA_{ti} * \ Contextual\ factor_{ti}) + \ r_{ti} \end{aligned}$$

Level 2

$$\beta_{0j} = \gamma_{00} + \gamma_{01}\ (Age_i) + \gamma_{02}\ (Sex_i) + \gamma_{03}\ (SES_i) + \mu_{0i}$$

$$\beta_{(1-8)0} = \gamma_{(1-8)0} + \mu_{(1-8)i}$$

where level-1 estimates the within person-effects on core affective state for each participant (subscript i) at each prompt (subscript t). Beta-coefficients were estimated for the average intercept across all participants (β_{00}), the within-person effects of the day of the week (β_{10}), time of day (β_{20}), weather (β_{30}), temperature (β_{40}), being outdoors (β_{50}), social context (β_{60}), and MVPA (β_{70}), and the interaction term between MVPA and either the physical environment or social context (β_{80}). Level-2 estimates the between-person effects of age (γ_{01}), sex (γ_{02}) and SES (γ_{03}). The random intercept is represented as μ_{0i}, and the random slopes for within-person effects (when significant variance in slopes was observed) are represented as $\mu_{(1-8)i}$.

Main analyses were conducted with all participants regardless of compliance. A sensitivity analysis was also conducted which only included participants who completed at least 50% of the EMA prompts (n = 91). Results from the sensitivity analysis are presented in Appendix G.

Results

Descriptive Statistics

Participant demographics and descriptive statistics for outcomes are described in detail in Chapter 3. In the 15-minutes before each prompt, participants participated in an average of 2.23 (SD = 2.34) minutes of MVPA. They participated in at least 5-minutes of MVPA in the 15-minute window before a prompt on 12.4% of occasions. Participants reported being outdoors for 10.0% of prompts, and they reported being with someone else for 75.4% of prompts.

Effects of MVPA, the Physical Environment and Social Context on Valence

Table 4.1 shows the results for the multilevel models on valence. Model 1 shows the direct effects of MVPA, the physical environment and social context on valence. Being outdoors at the time of a prompt had a small positive association with valence independent of the effects of MVPA. Participating in greater levels of MVPA in the 15-minutes before a prompt and being with someone else at the time of the prompt were not significantly related to valence. Models 2 and 3 show the moderating effect of the physical environment and social context on the within-person association between MVPA and valence, respectively. Results showed that the being outdoors or with someone else at the time of the prompt did not significantly moderate the association between MVPA and valence. Results from the sensitivity analysis (Appendix G) showed similar results when only including participants who completed at least 50% of sent EMA prompts.

Effects of MVPA, the Physical Environment and Social Context on Energetic Arousal

Table 4.2 shows the results for the multilevel models on energetic arousal. Model 1 shows that participants reported more energetic arousal when they were more active than usual in the 15-minutes before a prompt and when outdoors and with other people at the time of the prompt. However, results showed that there was a random effect for being outdoors, indicating that this effect varied significantly between individuals. Models 2 and 3 show the moderating effect of the physical environment and social context on the within-person association between MVPA and energetic arousal, respectively. Results showed that being outdoors or with someone else at the time of a prompt did not moderate the association between MVPA and energetic arousal. Results from the sensitivity analysis (Appendix G) were consistent with those of the main analysis.

Effects of MVPA, The Physical Environment and Social Context on Tense Arousal

Table 4.3 shows the results for the multilevel models on tense arousal. Model 1 shows the direct effects of MVPA, the physical environment and social context on tense arousal. Results showed that participating in greater levels of MVPA in the 15-minutes before a prompt and being outside or being with someone else at the time of a prompt was not significantly related to tense arousal. Models 2 and 3 show the moderating effect of the physical environment and social context on the within-person association between MVPA and tense arousal. Model 2 shows that the physical environment significantly moderated the within-person association between MVPA and tense arousal. There was an inverse association between MVPA and tense arousal when outdoors and a positive association between MVPA and tense arousal when indoors (Figure 4.1). Model 3 shows that being with someone else at the time of the prompt did not moderate the within-person association between MVPA and tense arousal. Results did not differ between the main analysis and the sensitivity analysis (Appendix G).

Table 4.1 Results from multilevel models predicting valence

	Model 1			*Model 2*			*Model 3*		
	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Fixed effects, model parameter									
Intercept, β_{00}	**11.38**	**2.78**	**<.001**	**11.36**	**2.78**	**<.001**	**11.38**	**2.78**	**<.001**
Sex (Female referent), γ_{01}	**0.56**	**0.28**	**.048**	**0.56**	**0.28**	**.046**	**0.56**	**0.28**	**.048**
Age, γ_{02}	-0.03	0.10	.769	-0.03	0.10	.768	-0.03	0.10	.768
SES, γ_{03}	-0.00	0.00	.964	-0.00	0.00	.970	-0.00	0.00	.964
Day of week (Weekend referent), β_{10}	-0.23	0.13	.074	-0.23	0.13	.073	-0.23	0.13	.077
Time of day (Morning referent), β_{20}									
Afternoon	**0.30**	**0.10**	**.002**	**0.30**	**0.10**	**.002**	**0.30**	**0.10**	**.002**
Evening	**0.43**	**0.10**	**<.001**	**0.44**	**0.10**	**<.001**	**0.43**	**0.10**	**<.001**
Weather (Fine referent), β_{30}									
Overcast	-0.22	0.12	.069	-0.22	0.10	.071	-0.22	0.12	.068
Raining	**-0.58**	**0.20**	**.003**	**-0.59**	**0.17**	**.003**	**-0.58**	**0.19**	**.003**
Temperature (Pleasant referent), β_{40}									
Too cold	**-0.32**	**0.10**	**.002**	**-0.32**	**0.10**	**.003**	**-0.31**	**0.10**	**.003**
Too hot	-0.28	0.17	.105	-0.27	0.17	.117	-0.29	0.17	.100
Physical environment (Indoors referent), β_{50}	**0.25**	**0.13**	**.044**	**0.13**	**0.13**	**.025**	**0.25**	**0.13**	**.043**
Social context (alone referent), β_{60}	0.06	0.10	.542	0.10	0.10	.578	0.06	0.10	.525
MVPA, β_{70}	0.01	0.02	.437	0.02	0.02	.253	-0.00	0.03	.920
MVPA * physical environment, β_{80}	-	-	-	-0.05	0.05	.304	-	-	-
MVPA * social context, β_{80}	-	-	-	-	-	-	0.02	0.04	.581
Fixed effects, model parameter									
Residual, r_{ti}	**1.92**	**0.08**	**<.001**	**1.92**	**0.08**	**<.001**	**1.92**	**0.08**	**<.001**
Intercept, μ_{0i}	**1.67**	**0.31**	**<.001**	**1.67**	**0.31**	**<.001**	**1.67**	**0.31**	**<.001**
Day of week, μ_{1i}	**0.51**	**0.12**	**<.001**	**0.51**	**0.12**	**<.001**	**0.51**	**0.12**	**<.001**
Weather, μ_{3i}	**0.18**	**0.09**	**.046**	**0.18**	**0.09**	**.046**	**0.17**	**0.09**	**.050**

SE = Standard error, bolded significant at p < .05

Table 4.2 Results from multilevel models predicting energetic arousal

	Model 1			***Model 2***			***Model 3***		
	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Fixed effects, model parameter									
Intercept, β_{00}	**9.57**	**3.42**	**.006**	**9.57**	**3.41**	**.006**	**9.55**	**3.42**	**.006**
Sex (Female referent), γ_{01}	**0.82**	**0.34**	**.019**	**0.82**	**0.34**	**.018**	**0.81**	**0.34**	**.020**
Age, γ_{02}	0.06	0.13	.647	0.06	0.13	.653	0.06	0.13	.652
SES, γ_{03}	-0.00	0.00	.563	-0.00	0.00	.565	-0.00	0.00	.568
Day of week (Weekend referent), β_{10}	**-0.59**	0.17	.001	**-0.59**	**0.17**	**.001**	**-0.58**	**0.17**	**.001**
Time of day (Morning referent), β_{20}									
Afternoon	**0.76**	**0.18**	**<.001**	**0.76**	**0.18**	**<.001**	**0.76**	**0.18**	**<.001**
Evening	0.34	0.18	.063	0.35	0.18	.056	0.35	0.18	.061
Weather (Fine referent), β_{30}									
Overcast	**-0.50**	**0.15**	**.001**	**-0.50**	**0.15**	**.001**	**-0.50**	**0.15**	**.001**
Raining	**-0.98**	**0.26**	**<.001**	**-0.98**	**0.26**	**<.001**	**-0.99**	**0.26**	**<.001**
Temperature (Pleasant referent), β_{40}									
Too cold	**-0.43**	**0.16**	**.007**	**-0.43**	**0.16**	**.007**	**-0.42**	**0.16**	**.008**
Too hot	**-0.58**	**0.26**	**.025**	**-0.57**	**0.26**	**.030**	**-0.59**	**0.26**	**.024**
Physical environment (Indoors referent), β_{50}	**0.83**	**0.25**	**.001**	**0.92**	**0.26**	**.001**	**0.83**	**0.25**	**.001**
Social context (alone referent), β_{60}	**0.44**	**0.15**	**.003**	**0.43**	**0.15**	**.004**	**0.45**	**0.15**	**.002**
MVPA, β_{70}	**0.11**	**0.03**	**<.001**	**0.13**	**0.03**	**<.001**	0.06	0.05	.274
MVPA * outdoors, β_{80}	-	-	-	-0.10	0.07	.178	-	-	-
MVPA * social context, β_{80}	-	-	-	-	-	-	0.07	0.06	.250
Random effects, model parameter									
Residual, r_{ti}	**4.26**	**0.18**	**<.001**	**4.26**	**0.18**	**<.001**	**4.25**	**0.18**	**<.001**
Intercept, μ_{0i}	**2.33**	**0.45**	**<.001**	**2.33**	**0.45**	**<.001**	**2.33**	**0.45**	**<.001**
Day of week, μ_{1i}	**0.79**	**0.21**	**<.001**	**0.80**	**0.21**	**<.001**	**0.79**	**0.21**	**<.001**
Time of day, μ_{2i}	**0.43**	**0.14**	**.003**	**0.42**	**0.14**	**.004**	**0.42**	**0.14**	**.004**
Physical environment, μ_{5i}	**1.83**	**0.72**	**.011**	**1.70**	**0.69**	**.013**	**1.86**	**0.72**	**.010**

SE = Standard error, bolded significant at $p < .05$

Table 4.3 Results from multilevel models predicting tense arousal

	Model 1			***Model 2***			***Model 3***		
	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Fixed effects, model parameter									
Intercept, β_{00}	**7.36**	**2.67**	**.002**	**7.32**	**2.67**	**.002**	**7.36**	**2.67**	**.002**
Sex (Female referent), γ_{01}	**-0.56**	**0.27**	**.040**	**-0.55**	**0.27**	**.043**	**-0.56**	**0.27**	**.039**
Age, γ_{02}	-0.06	0.10	.576	-0.05	0.10	.578	-0.06	0.10	.575
SES, γ_{03}	-0.00	0.00	.561	-0.00	0.00	.569	-0.00	0.00	.561
Day of week (Weekend referent), β_{10}	0.12	0.14	.407	0.11	0.14	.413	0.12	0.14	.400
Time of day (Morning referent), β_{20}									
Afternoon	-0.16	0.12	.169	-0.16	0.12	.170	-0.16	0.12	.173
Evening	**-0.35**	**0.13**	**.005**	**-0.34**	**0.12**	**.007**	**-0.35**	**0.13**	**.005**
Weather (Fine referent), β_{30}									
Overcast	0.10	0.12	.409	0.10	0.12	.393	0.10	0.12	.411
Raining	0.11	0.21	.589	0.10	0.21	.622	0.11	0.21	.596
Temperature (Pleasant referent), β_{40}									
Too cold	0.24	0.15	.111	0.24	0.15	.102	0.24	0.15	.109
Too hot	**0.66**	**0.24**	**.006**	**0.69**	**0.23**	**.004**	**0.66**	**0.24**	**.006**
Physical environment (Indoors referent), β_{50}	-0.14	0.15	.349	-0.03	0.16	.849	-0.14	0.15	.351
Social context (alone referent), β_{60}	0.07	0.12	.531	0.06	0.12	.607	0.07	0.12	.522
MVPA, β_{70}	0.04	0.02	.054	**0.06**	**0.02**	**.006**	0.03	0.04	.509
MVPA * outdoors, β_{80}	-	-	-	**-0.13**	**0.06**	**.021**	-	-	-
MVPA * social context, β_{80}	-	-	-	-	-	-	0.02	0.05	.748
Random effects									
Residual, r_{ti}	**2.80**	**0.11**	**<.001**	**2.79**	**0.11**	**<.001**	**2.80**	**0.11**	**<.001**
Intercept, μ_{0i}	**1.35**	**0.29**	**<.001**	**1.35**	**0.29**	**<.001**	**1.35**	**0.29**	**<.001**
Day of week, μ_{1i}	**0.54**	**0.14**	**<.001**	**0.55**	**0.14**	**<.001**	**0.54**	**0.14**	**<.001**
Temperature, μ_{4i}	**0.28**	**0.12**	**.021**	**0.27**	**0.12**	**.024**	**0.28**	**0.12**	**.021**

SE = Standard error, bolded significant at p < .05

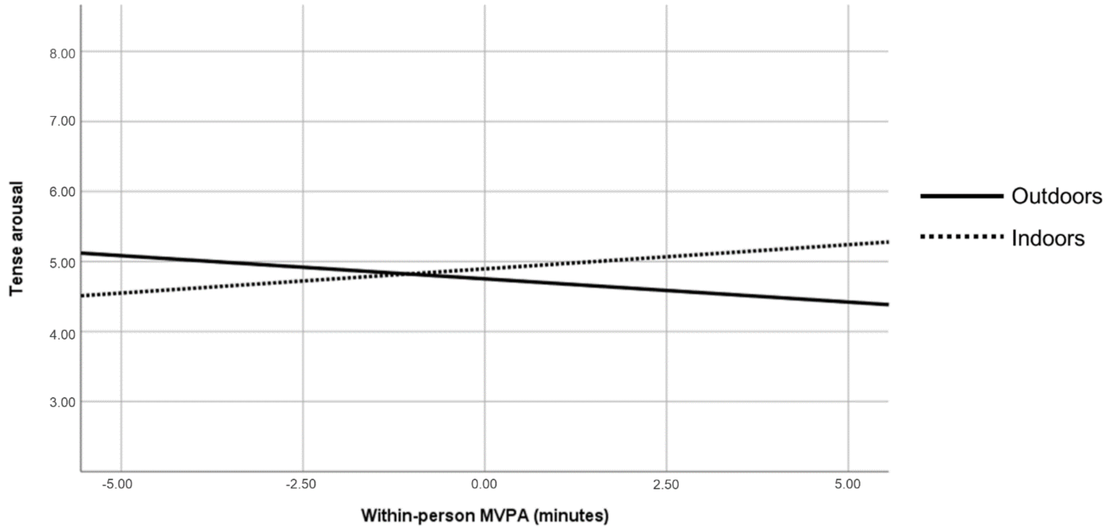

Figure 4.1 Within-person relationship between MVPA and tense arousal when indoors vs outdoors

Discussion

This study aimed to determine whether there was an independent association between MVPA, the physical environment and social context on valence, energetic arousal, and tense arousal in a sample of adolescents. The results provided mixed support for the study hypotheses. In support of the study hypotheses, participating in more MVPA than usual, being outdoors and being with someone else was all independently positively associated with energetic arousal. Additionally, being outdoors at the time of a prompt was positively associated with valence. Contrary to hypotheses, the findings revealed that the level of MVPA and being with someone else was not independently associated with valence, and level of MVPA, being with someone else, and being outdoors were not independently related to tense arousal. The study also aimed to determine whether the physical environment and social context moderated the within-person association between MVPA and valence, energetic arousal, and tense arousal. In support of the study hypothesis, the physical environment moderated the association between MVPA and tense arousal such that participating in greater levels of MVPA than usual outdoors was associated with less tense arousal, whereas participating in greater levels of MVPA than usual indoors was associated with more tense arousal. However, contrary to the study hypotheses, the physical environment did not moderate the association between MVPA and valence or energetic arousal, and the social context did not moderate the association between MVPA and valence, energetic arousal, or tense arousal.

The current study provides further evidence about the benefits of being outdoors on affect, independent of levels of MVPA. The positive association between being outdoors with energetic arousal and valence, independent of levels of MVPA, shows that there are added benefits of being physically active outdoors. This is consistent with previous research that found that children reported significantly greater positive affect when they reported being active outdoors and in their yard compared to when they were active inside (Dunton, Liao, Intille, Wolch, et al., 2011). However, the current study found that being outdoors was not related to feelings of tense arousal. It has been suggested that to reduce tense arousal, natural environments need to be perceived as far away from daily tasks, fascinating, and expansive (Kaplan, 1995). For example, Mennis et al. (2018) found that the stress-reducing effects of exposure to greenspace only occurred when adolescents experienced the greenspace away from their home. Additionally, Ulrich et al. (1991) suggests that environments that have arousal increasing properties, including intensity, complexity, and movement, such as urban environments, are unlikely to reduce feelings of stress. Therefore, it may be essential to provide young people living in urban and suburban neighbourhoods access to greenspaces such as parks and fields, which may potentially decrease tense arousal to a greater extent than urban landscapes.

Although being outdoors at the time of a prompt was not directly associated with tense arousal in the current study, the results did show that being outdoors interacted with levels of MVPA to predict tense arousal. The direction of this interaction indicated that participating in greater levels of MVPA than usual outdoors decreased tense arousal, whereas participating in more MVPA than usual indoors increased tense arousal. This is consistent with research that found that there was only an inverse within-person relationship between being active and negative affect in adults when they were active outdoors (Dunton et al., 2015). This could be because being physically active outdoors may be perceived as less exerting than being physically active indoors (Dasilva et al., 2011; Krinski et al., 2017), and therefore could be regarded as a less agitating experience. The current study showed that being outdoors did not moderate the association between MVPA and energetic arousal or valence, consistent with research in adults that found that being outdoors did not moderate the association between self-reported MVPA and positive affect in daily life (Dunton et al., 2015). This indicates that although there may be added benefits to being physically active outdoors, the direction and strength of the relationship between MVPA and valence and energetic arousal does not differ based on the physical environment.

The finding that the social context was associated with energetic arousal, independent of levels of MVPA, but was not related to valence or tense arousal indicates that there may be limited added benefits to being active with others. Additionally, findings from the present study showed that the social context did not interact with MVPA to predict valence, energetic arousal or tense arousal, suggesting that the strength and direction of the relationship between MVPA and affect did not differ by social context. Similarly, research involving older adults has shown that being with someone else did not moderate the relationship between device-measured physical activity and valence or energetic arousal (Cabrita et al., 2017; Kanning & Hansen, 2016). However, it was found that being with someone else did moderate the association between device-measured physical activity and tense arousal in older adults (Kanning & Hansen, 2016). The findings regarding the social context in the current study might be due to how the social context was measured. Although measuring whether participants were with someone else or alone at the time of each prompt measured the presence of social interactions, it did not measure the participants' experience of these interactions. It is possible that the quality of the relationship people share with those around them may influence affect to a greater extent than the quantity of social interactions. For example, in their meta-analysis, Liu et al. (2019) found that the quality of social interactions had a stronger effect on positive and negative affect than the number of social interactions. Therefore, results could be different if the quality of social interactions were considered. Additionally, the within-person association between social interactions and affect may depend upon who the social interaction is with. For example, previous research with adolescents has demonstrated that interactions with friends have a more favourable within-person association with affect than interactions with family members (Schneiders et al., 2007; Silk et al., 2011).

Considering the results from this chapter and the previous chapter, future research should test the existence of a three-way interaction where the effect of the physical and social contexts differ based on distinct domains of physical activity. Additionally, future research may consider whether the physical and social context mediates the within-person association between domain specific MVPA and affect. For example, is it possible that recreational physical activities have a more favourable within-person association with affect because it is more likely to be completed outdoors than household physical activity and with others compared to active travel?

Although this study adds to our understanding of the conditions under which MVPA will have the most positive effect on valence, energetic arousal and calmness, limitations of the current study must be considered. First, participants only reported being outdoors for 10% of the prompts. Although this is similar to patterns identified in other studies (e.g., Wheeler et al., 2010), it resulted in a limited number of data points when estimating the effect of being outdoors on outcomes. Additionally, participants were asked to report their physical environment and social context when completing an EMA prompt. Therefore, it is possible that the physical environment or social context reported at EMA prompts may not have accurately captured the physical activity context in some instances (e.g., if a participant went indoors just before completing a prompt). Using GPS triggered or event contingent sampling could have captured a greater proportion of outdoor physical activities and provide more accurate information about the physical environment and social context of participants' MVPA. Second, operationalizing the social context as alone or not alone does not accurately capture components of social interactions such as the type or quality of social interactions which could have unique influences on affect.

Conclusion

This study showed that, for adolescents, being outdoors was independently associated with valence and energetic arousal and that being outdoors moderated the association between MVPA and tense arousal. This suggests that young people should be encouraged to spend more time outdoors and emphasizes the importance of supporting adolescents to be physically active outdoors to experience more favourable affect while physically active. This study showed that being with someone else was positively associated with energetic arousal, but not valence or tense arousal, and did not moderate the association between MVPA and valence, energetic arousal or tense arousal. Future research should consider whether the quality of social interactions may add to or augment the association between MVPA and affect.

Chapter 5: A Qualitative Analysis of Factors Influencing the Association between Physical Activity and Affect

Introduction

Although the quantitative results from the preceding chapters begin to elucidate potential moderators of the association between physical activity and affect, using qualitative methods may further enhance our understanding of these mechanisms (Creswell & Planco Clark, 2011). Employing such a sequential explanatory mixed methods design provides complementary results, which can enhance or clarify the quantitative findings and provide new insights that may not be obvious from quantitative results (Moran et al., 2011; Ryba et al., 2020). For example, although results from the previous chapter suggest that the social context did not moderate the association between MVPA and affect, qualitative data may provide insights into the specific circumstances during which social context favourably influences the association between MVPA and affect.

There is a growing body of evidence from qualitative studies that have examined the factors that influence individuals' affective experiences during physical activity. One of these studies examined how adolescents' perceptions of physical activities in daily life influenced their affective experience (White, Olson, et al., 2018). Results from this study demonstrated that when adolescents perceived that physical activities were fun and enjoyable, autonomously motivated, provided a distraction, promoted a sense of belonging, and were optimally challenging, they were perceived to be associated with a more positive affective experience. Alternatively, physical activities that participants were not interested in, forced to participate in, and were too difficult were associated with a negative affective experience. Some participants also discussed the negative influence of others, such as a sense of feeling judged, could lead to a negative affective experience while being physically active. Similar findings were reported in another study in which adolescents who discussed having a choice and a sense of control over the activity, feeling confident in their ability to complete the physical activity, and enjoyment of physical activity experienced more positive valence while completing a self-paced bout of MVPA in a controlled laboratory setting (Stych & Parfitt, 2011).

Multiple studies have also examined factors that influence adults' affective experience during physical activity in daily life. In one of these studies, participants described having a more positive affective experience during physical activities when they felt competent, the activity was novel, they experienced positive physiological and psychological responses to the activity, and the activity was completed with other people (Wienke & Jekauc, 2016). Interestingly, though, some participants also described a positive affective experience during physical activities completed alone, and that this was seen as a time for relaxation. Another study qualitatively examined factors that were related to recalled valence in a sample of mainly undergraduate university gym members immediately after completing a session at the gym (Beaumont et al., 2021). Researchers found that participants who felt more ready to be physically active (i.e., not tired, hungry, dehydrated, or sore), felt like they performed well, enjoyed their workout, and felt being physically active was a stress reliever, reported more positive recalled valence (Beaumont et al., 2021).

Multiple studies have also elicited adults' perceptions of factors that influenced their experiences of affect while completing an experimental bout of MVPA in controlled laboratory settings. In multiple studies of women, researchers found participants who had a more positive perception of their ability, more positive perceptions about the outcomes of exercise, did not focus on interoceptive cues during the activity, and perceived they had control over the activity experienced more positive affect during a bout of MVPA (Rose & Parfitt, 2007; Rose & Parfitt, 2010).

Some studies have also qualitatively examined participants' perceptions of affective beliefs related to physical activity. Common reasons why participants held positive affective beliefs about physical activities included the physical activity provided them with an opportunity to socialize with others, leads to positive physical and psychological outcomes, is enjoyable, is autonomously motivated, is optimally challenging, and provides a distraction (Bellows-Riecken et al., 2013; Calder et al., 2020; Ruissen et al., 2019). Additionally, participants who feel more confident in their ability to complete physical activities held more positive affective attitudes, and participants held more positive affective attitudes towards physical activities undertaken in a physical environment they like (Bellows-Riecken et al., 2013; Calder et al., 2020).

Although previous qualitative studies provide insights into factors that people perceive to be associated with experiencing more positive affect while physically active, few of these studies examined adolescents' perceptions of factors that influence affect experienced during physical activity. Many of these studies also elicited participants' perceptions of a physical activity completed in a controlled laboratory setting or affective beliefs about physical activity, as opposed to affective experiences in daily life. Additionally, none of these studies examined factors that participants believe lead to feeling more pleasurable, more energetic, and less tense when physically active. Therefore, this study aimed to qualitatively investigate factors that adolescents perceive to lead to experiencing more positive valence, more energetic arousal, and less tense arousal while physically active. To achieve this aim, this study will answer the following research question: What factors do adolescents perceive lead to experiencing more positive valence, more energetic arousal, and less tense arousal while physically active?

Methods

Epistemological Approach

Although the other chapters of this thesis use quantitative research methods and thus by design employ a realist ontological and objectivist epistemological paradigm, this does not mean that such a positivist world view needs to be applied to this qualitative component of the study. Rather, Creswell and Planco Clark (2011) advocate that more than a single worldview can be used in a mixed-methods study, and the worldview employed at each stage of a mixed-methods study should be chosen based on the type of mixed methods design. Thus, a constructionist epistemological and relativist ontological paradigm was employed for this qualitative component of the thesis. This worldview proposes that there are multiple realities and meanings are subjective; thus no single reality of experiences exists (McGannon et al., 2019; Smith & McGannon, 2018). This approach allows researchers to elicit multiple meanings from participants, which may give a deeper understanding and add depth to the quantitative results from the preceding chapters (Creswell & Planco Clark, 2011).

Participants and Procedures

All 125 participants in the EMA study were invited to participate in this qualitative study. Of these, 15 adolescents agreed to participate (12% response rate).

The sample consisted of 10 boys and five girls, and the average age of participants was 13.93 years. Participants in this qualitative study engaged in an average of 102.49 (SD = 46.96) minutes of device-measured MVPA per day. This is slightly lower than the levels of MVPA reported by the overall sample (see results in Chapter 6).

Adolescents who agreed to participate in this study were invited to participate in a semi-structured one-on-one interview between May and September 2020. Given that this study was conducted during a COVID-19 lockdown, interviews were conducted and recorded online via Zoom (Zoom Video Communications, Inc.; San Jose, CA). At the beginning of the interview, participants were informed of the purpose of the study and how the data they provided would be used. At the outset of the interview, participants were asked to define physical activity to gauge their understanding of the topic. Additionally, each participant was then read the following definition of physical activity:

> *"For the purpose of this interview, we will define physical activity as any type of bodily movement that raises your heart rate, even slightly, so this includes things like playing organised sport, including training, walking or cycling to get to places, doing chores around the house, playing physically active games with friends, and participating in school PE."*

To elicit participants' perceptions of factors that may explain the association between physical activity and affect, participants were asked to describe physical activities that they found pleasurable, calming, and energising. Additionally, participants were asked to describe *why* they found participating in these activities pleasurable, calming, and energising. Because interviews were conducted during a COVID-19 lockdown, participants were also asked if there were any pleasurable activities that they participated in before the lockdown, but were unable to do during lockdown, and what they missed most about these activities. The interview schedule can be found in Appendix H.

Data Analysis

Before analysis, interview recordings were transcribed verbatim. Transcripts were analysed using (reflexive) inductive thematic analysis, where the analysis was data driven, and codes and themes were determined based on what participants said (Braun & Clarke, 2006, 2020). Therefore, data was not mapped onto any preconceived constructs, instead, data was extracted about what participants themselves perceived to influence experiences of valence, energetic arousal, and tense arousal while participating in physical activities.

First, the transcripts were read and re-read to ensure familiarity with the data. After data familiarisation, the transcripts were coded in NVivo 12 (QSR International Pty Ltd., Melbourne, Australia). Parts of the transcript could be assigned multiple codes. Once the data were coded, similar codes were collated to form initial themes. Themes were checked against codes to ensure that all codes were related to the theme, and against the data to ensure that no important ideas were missing from themes. Once themes were reviewed, they were named, and are discussed in the results section below, with supporting quotes. The quotes were labelled with a participant's pseudonym, which was a letter for boy (B) or girl (G), and participant number (between 1-10 for boys and 1-5 for girls).

Given the researcher's subjectivity in the analysis of codes and themes, it is important to recognise their reflexive engagement in interpreting the data. To address this reflexivity and increase rigour in the analysis, critical dialogue was had with a critical friend, where alternative explanations and interpretations of the data were reflected upon (Smith & McGannon, 2018). For this study, the critical friend was the Primary Supervisor of the Higher Degree by Research Student.

Results

A total of six themes regarding factors that influence the association between physical activity and affect were formed by the researcher in the thematic analysis: finding activities fun and enjoyable, having control over the activity, the social context of the physical activity, provides a welcome distraction, getting outdoors, and physiological and psychological benefits of getting moving. Each of these themes are discussed in detail below.

Finding Activities Fun and Enjoyable

Many participants identified participating in physical activities that they perceived to be fun and enjoyable when explaining why participating in a physical activity was a pleasurable experience. For example, when describing why they found swimming pleasurable, one participant stated:

> *"Um, yeah I really enjoyed swimming because I liked being in the water and it's, it's sort of like you're flying and you really get to fly, you are really moving your body. My favourite's backstroke and I like the*

arm movements and the movements of your legs. It's quite pleasant." (G3)

Similarly, when describing why they found participating in gymnastics a pleasurable experience, one participant described how much fun they had participating in the activity:

> "*Probably, probably doing forward rolls on really high stuff. So, you've got like big, you've got like a ridiculous pile of mats, of like mattresses and you've got to like a jump and forward roll over them. It's crazy hard, but it's a lot of fun."* (G4)

Participants identified several reasons why they found physical activities fun and enjoyable including, because it is something that they are good at: "*I'm just good at it and it's fun*" (G4), being able to do the activity with friends: "*Because I enjoy football and enjoy just being around having a kick with some of my mates*" (B7), or because it's an opportunity to get outside:

> "*Most of the time because when you're inside just doing schoolwork for most of the day, and then you finally get like, you finally get it done and you get to go outside. That's a really enjoyable experience because it's just like you can get away from the house because you're inside most of the day and it's good to just get out*." (B6)

Some participants also discussed that activities that they enjoy were more calming. When describing why they found going for bike rides and playing basketball calming, one participant said: "*I just kind of enjoy riding and playing basketball. So yeah, just kind of enjoy those activities*" (B6). Although participants identified participating in fun and enjoyable activities as more pleasurable and calming, participants did not discuss fun and enjoyable activities being more energising.

Having Control Over the Activity

Another factor that participants identified as something that made a physical activity a pleasurable experience was having control over the activity. For example, explaining why they found going for walks on their own pleasurable, one participant stated:

> "*Because usually when I'm physically active it's because my parents have forced me to get out of bed and do something and if I go walking with my dad, then he's going to complain. I'm going too slow. And if I do it with my mum, then she's going to want to talk the whole time. And I don't want to talk to her while I'm going for a walk. So, I'm trying to listen to music and I don't want to have someone judge my pace. So I sort of just you know, go on my own cos I'm fine with my speed*." (G4)

Multiple participants discussed being able to go at their own pace as something that made a physical activity pleasurable. One participant described finding bike riding alone pleasurable because they did not have to keep up with others: "*Um, I just get to, I can go at my own pace, I don't have to worry about keeping up with anyone*" (B2), while another discussed how they liked how their pace wasn't dictated by others: "*I can go at my own pace and I didn't have to listen to anyone*" (B1).

Participants also talked about not being forced to participate in a physical activity and getting to choose to participate in a physical activity was more pleasurable. When comparing taking their dog for a walk and walking to school, one participant described walking their dog as pleasurable because "*it's less that I'm forced to do it, it's more like, I do it because I want to do it*", whereas they do not find walking to school pleasurable because it is "*something that I couldn't really avoid doing*" (B4). Additionally, when asked to describe a physical activity that they find pleasant, another participant described how the type of physical activity did not matter, as long as it was an activity that they chose to do:

> "*I just, I guess I love just being out running around doing anything that involves sort of getting up and moving. So any sport. I just like even just training hard. Something I choose to do*." (B9)

Participants did not describe having control over the physical activity they were participating in as something that made being physically active more calming or more energising.

The Social Context of the Physical Activity

Participants regularly identified the social aspect of being physically active as something that made it a pleasurable experience. As described earlier, participants discussed the opportunity to be active with a friend as something that made an activity enjoyable and pleasurable. Additionally, participants described how being active with others can help them get more involved with activities:

"*Um, it's nicer than being on your own, like you can talk, while you do your physical activity. Like you can, it sort of helps you get involved in it more. Like get more committed to it*." (G1)

Having an opportunity to be active with friends during lockdown was something that participants found especially pleasurable. For example, one participant discussed the opportunity of being physically active with his friend during lockdown:

"*And also, like getting out with a friend and actually communicating with them rather than just over like the internet and having no contact with anyone. I liked, you know getting together with him and doing that stuff*." (B6)

However, some participants could not be active with their friends during lockdown but described it as something that they missed about pleasurable physical activities the most. For example, when asked to describe what they miss most about physical activities they were not able to participate in during lockdown, one participant stated:

"*Probably just the social interaction just being there with my mates having a laugh around at training and not being able to take it all seriously, but when you're by yourself it's just train, train, train*." (B9)

As well as being active with friends, participants also discussed how they found being part of a team pleasurable. When describing why they find playing soccer pleasurable, one participant stated:

"*Well, I like mainly, I like soccer because you're doing it with people, and you get to do it as a team*." (G5)

Others talked about how they like the encouragement they receive from others when being physically active as part of a team. When describing why they find being part of a basketball team pleasurable, one participant explained: "*Just like encouraging each other and there's a bit of competition and we can learn from each other*" (G2).

Although many participants found the social aspect of physical activity pleasurable, some participants found being active by themselves more pleasurable because it meant they had more control over what they were doing, and others did not judge them. For example, one participant described why they find going for walks early in the morning when no one else is out more pleasurable:

> "*I'd say my morning walks a pretty good. I don't know. I just crank my music up really loud in my headphones ignore the fact that, you know ignore that anyone else is walking. Although usually it's like 7 o'clock in the morning and you know, you're in quarantine, so who wants to have to get up that early? So usually like it's pretty peaceful out there. So, just I enjoy that … I do a lot of dancing while I'm walking. Because no one's there to see me and I just casually ignore them*." (G4)

Additionally, some participants found being active alone more calming. For example, when asked to describe a physical activity that they found calming, one participant stated:

> "*I reckon probably my bike riding would do that role because like I do that alone most of the time so it's kind of like time to yourself to think and get away from the crowded space of the house*." (B6)

Similarly, when describing why they found being active alone calming, one participant described it as an opportunity to be with their own thoughts: "*it's just nice to be alone with my thoughts*" (G4).

Participants did not describe the social context as influencing how energising participating in a physical activity was.

An Opportunity to Get Outdoors

Another factor that explained why adolescents found participating in physical activity pleasurable was being able to get outdoors while physically active. As discussed earlier, adolescents found participating in physical activities outdoors an enjoyable experience. In addition to finding it enjoyable, participants also discussed how they liked the opportunity to get out of the house and experience the natural elements. When describing why they found going for bike rides after school pleasant, one participant stated: "*Well, it's just a chance to get out and have some fresh air*" (B2). Others described how they found going for walks a pleasant opportunity to get out of the house and see some scenery:

> "*It was good to … be out of the house somewhere other than home. But I also think it was nice to see the scenery and actually move properly."* (G3)

> "*Well in terms of walking I like the scenery*." (B5)

Some participants also described getting outdoors as a reason that being physically active may be calming. When asked to describe a physical activity that they found calming, one participant said:

"*Well I guess going outside, getting fresh air is good. So that helps. Um, so maybe just exercising outside*." (B4)

Another participant discussed how they found exercising outdoors more calming because it was refreshing:

"*I think because I think it's like the endorphins when you get outside instead of like being inside all day when you get outside, it's just yeah, it's more refreshing*." (G2)

Getting outside was also something that made being physically active a more energising experience for some participants. When describing their preference for being active indoors or outdoors when they needed a pick-me-up, multiple participants described their preference for being active outdoors:

"*I prefer outside, I generally try and get outside whenever I do physical activity*." (B6)

"*Yeah, well getting outdoors, or even to the back yard. Just getting off my ass and getting blood flowing a little bit*." (B7)

Provides a Welcome Distraction

Many participants described physical activity being a distraction from other things happening in life as something that made being physically active calming. These results may be particularly salient in the context of the COVID 19 lockdowns that were in place at the time the data were collected When describing why they find going for bike rides or walks calming, one participant stated: "*it's easier for me just to forget about what's happening and just enjoy life*" (B1). Participants talked about how calming physical activities were ones in which they were in the moment, and their attention was focused on the activity: "*they kind of take my mind away from everything else. I just think about what I'm doing instead of what's going on everywhere else*" (B7). When talking about how they found practicing basketball calming, one participant described:

> "*I don't know I guess it's just being in that moment by myself sort of not being able to think about other stuff. Just focusing on me myself and I guess the sport so just sort of made me block everything out*." (B9)

Similarly, discussing going for bike rides during lockdown, one participant described how they felt in the moment, and it cleared their mind:

> "*Yeah, it kind of clears your mind. So you don't think about, like I don't stress as much and I'm doing stuff because you're not thinking about it. You're just kind of in the moment when you're doing activities*." (G5)

Interestingly, some participants also discussed focusing on the activity as something that may make the activity more energising. When discussing why they feel more energetic during soccer, one participant stated:

> "*I think just activities like soccer, where you're doing stuff and doing tricks and stuff and your kind of focusing on what you're doing. It just makes you feel more energetic than if you're just sitting around doing something or stressing about work*." (G5)

Although identified as a factor influencing whether participating in physical activity was calming and energising, participants did not discuss physical activities providing a distraction as something that made them more pleasurable.

Physiological and Psychological Benefits of Getting Moving

The most commonly discussed reason that physical activities were energising was that adolescents felt that just getting up and moving gave them a burst of energy. When asked to describe a physical activity that makes them feel energetic, one participant said:

> "*Um, probably the boxing workouts. And I think it's because, I think just getting your body moving if you're like sitting down or laying down all day, whether it's doing work or watching TV or something, your body is just resting, but if it's working then it gets more energized*." (G2)

Getting a burst of energy after getting up and moving was a view shared by multiple participants:

> "*Ah, just getting out and doing something instead of being stuck at home sitting on the couch, or in bed. Just getting out and moving around*." (B7)

> "*Just like standing up, moving, rather than just sitting down*." (B4)

> "*Yeah, it does make me feel more energetic. It's weird how you feel tired so you don't really feel like doing it, but when you do it, you feel less tired afterwards*." (G3)

However, some participants described how more intense physical activities would make them feel more tired than it would make them feel energetic:

> Participant: *"I find like going for a walk and stuff kind of more tiring than energising*."
>
> Interviewer: "*Really, why's that?*"
>
> Participant: "*I don't really know. There's a lot of hills right around where I walk so maybe that's it.*" (B5)

Additionally, when describing whether they felt more energized during swimming or dancing, one participant stated: "*swimming, because it's more intensive, doesn't [energise me] as much as dance would*." (G1)

Some participants also described that just getting moving made them feel pleasure while active. For example, when describing why they found playing soccer a pleasurable experience, one participant said: "*Like, running around doing stuff makes you feel better than if you're just sitting around*" (G5). Others talked about experiencing an endorphin high: "*Like when you're exercising, there's always endorphins and you know stuff like that*" (B5), a burst of adrenaline: "*it's, I guess a burst of adrenaline*" (B9), or just feeling good: "*I was just vibing man*" (B10) which made participating in a physical activity pleasurable.

Some participants also talked about how they found activities pleasant because they felt a sense of reward for moving their body: "*The reward of like knowing your like working your body doing exercise*" (G2). When describing why they found playing basketball pleasurable, one participant stated:

"*All the sense of actually doing something like you feel like you haven't been a couch potato. You're actually doing something with your life.*" (B6)

Some participants also discussed experiencing an endorphin high as a reason that they found participating in physical activities calming:

"*I think because, I think it's like the endorphins when you get outside instead of like being inside all day when you get outside, it's just yeah, it's more refreshing*." (G2)

Participants also described how being physically active was relaxing and released stress: "*It's sort of just gives you free time to relax and release stress*." (G3)

Discussion

This study aimed to qualitatively investigate factors that adolescents perceive to lead to more positive valence, more energetic arousal, and less tense arousal while physically active. Some factors were discussed by participants for all dimensions of affect, whereas other factors were specific to one or two dimensions of affect. For valence, participants described participating in fun and enjoyable physical activities, having control over the physical activities that they participated in, getting outdoors when active, the social context of the physical activity, and perceiving positive psychological benefits from getting moving as factors that influenced whether participating in physical activity was a pleasurable experience. For energetic arousal, participants described perceived physiological benefits of getting moving, getting outdoors when active, and physical activity providing a distraction as factors contributing to physical activities being energising. For tense arousal, participants described the physical activity providing a distraction, getting outdoors when active, the activity being fun and enjoyable, being active alone, and the perceived psychological benefits of getting moving as factors that made being physically active more calming.

Getting Outdoors

The findings from this qualitative study further highlight the potential added or synergistic effect of being physically active outdoors on valence, energetic arousal and tense arousal. These results complement the findings from Chapter 4, and further underscore the need to provide appealing outdoor spaces where young people can be physically active. Some participants described having the opportunity to get out of the house and enjoy the natural elements, such as the scenery, as what makes being physically active outdoors more pleasurable. Other researchers have also found that being active outdoors may be associated with a more positive affective experience because of the novelty of being outside and enjoying the landscape, which contrasts with being inside all day (Wienke & Jekauc, 2016). This is consistent with the attention restoration theory, which states that natural environments can hold an individual's attention (Kaplan, 1995) and previous research which shows that people have a more external attentional focus and more pleasurable experience when physically active in natural outdoor environments compared to indoors (Krinski et al., 2017). This points to the potential additional benefits of being physically active in natural green spaces.

Other participants discussed just getting outdoors and getting some fresh air as something that made being physically active more pleasurable, energising and calming. This is in line with previous research, which found that adolescents report more positive affect and energy when outdoors (Bejarano et al., 2019; Dunton, Liao, Intille, Wolch, et al., 2011). Therefore, environments that encourage young people to engage in physical activities outdoors in their neighbourhoods rather than indoors, such as communities designed based on smart growth principles (Dunton et al., 2012b; Jerrett et al., 2013), may also promote more favourable affective outcomes during physical activity by encouraging young people to be active outdoors.

The Social Context

The results from this chapter demonstrated that some adolescents find being physically active with others, especially friends or being part of a team, more pleasurable. In contrast, some participants discussed how they find being physically active alone more pleasurable. This is consistent with previous qualitative research, which has demonstrated that social contexts might promote a sense of belonging in adolescents during physical activity and therefore contribute to a positive affective experience; however, being active with others may also have a negative influence, such as feeling judged, which is linked to negative affective experiences while active (White, Olson, et al., 2018). This may explain why the social context did not moderate the association between physical activity and valence in Chapter 4.

Some participants discussed how they had a sense of a meaningful connection with those with who they were active, fulfilling the psychological need for relatedness (Ryan et al., 2009; Wilson et al., 2008), making participating in physical activity more pleasurable. Additionally, others talked about how being active as part of a team helped them learn from each other, helping fulfil the need for competence (Wilson et al., 2008). However, other adolescents discussed how they preferred to be physically active alone because it meant that they had more control over the activities they were participating in, and felt less judged while active, which they found more pleasurable. This highlights the importance of others promoting the fulfilment of the basic psychological needs of autonomy, competence, and relatedness during physical activities, and the potential detrimental effect of others being controlling or coercive over physical activity (Ryan et al., 2009). Therefore, it may not simply be the social context that moderates the association between physical activity and valence, rather it may be how well the people an adolescent is physically active with support the fulfillment of the basic psychological needs that moderate the association between physical activity and valence. In some cases, the individuals an adolescent is active with may help fulfil these needs, while on other occasions, they may hinder the fulfilment of these needs.

Additionally, similar to other studies (Bellows-Riecken et al., 2013; Ruissen et al., 2019; White, Olson, et al., 2018), when discussing positive perceptions of being physically active with others, participants did so in terms of being active with friends and teammates. This indicates that being active with certain type of social groups (e.g. friends, teammates) could potentially have a positive association with valence, whereas being active with other social groups (e.g. family, strangers) may not.

Some participants also discussed how they found being active alone more calming. They described being active alone as an opportunity to get away from others and be alone with their thoughts. This is in line with a previous study that found that some participants enjoyed being physically active alone and found it more relaxing (Wienke & Jekauc, 2016). Therefore, being active alone may provide an opportunity for adolescents to escape daily stressors, clear their heads, and feel calmer and more relaxed.

Having Control Over the Activity

Adolescents' perceptions that activities over which they have control being more pleasurable may explain why recreational physical activities did not have a significant within-person positive association with valence in Chapter 3. It is possible that adolescents do not have control over all types of recreational physical activities, such as organised or competitive sports, with training drills set by coaches, and competition which is dictated by rules and procedures. Therefore, these forms of recreational physical activity may be perceived as less pleasurable than unorganised forms of recreational physical activities over which adolescents may have more control. For example, in an EMA study, researchers found that adolescents reported more positive valence after participating in unorganised recreational physical activities but not organised sports (Koch et al., 2020). The desire to have control over physical activities also supports the findings from the results in Chapter 3, that showed participating in active travel and household physical activities does not have a positive association with valence, potentially because these activities, as one participant stated, are activities that adolescents "couldn't really avoid doing".

Finding Activities Fun and Enjoyable

In addition to wanting to have control over the activities they are doing, participants also described finding activities that were fun and enjoyable as being more pleasurable. This is consistent with the SDT, which suggests that intrinsically motivated behaviours, which are motivated by enjoyment, are more likely to lead to more positive psychological outcomes (Ryan et al., 2009). This may explain why active travel and household physical activities did not have a positive within-person association with valence in Chapter 3. It is unlikely that adolescents' main motivations to participate in these domains of physical activity is because they find participating in them fun or enjoyable (White, Olson, et al., 2018). Additionally, although highly recreationally active teenagers may be intrinsically motivated to participate in recreational physical activities, less recreationally active adolescents may not be (Lawler et al., 2017). Therefore, less active youths may not find participating in recreational physical activities fun and enjoyable and therefore may not find it a pleasurable experience.

Participants also described the context of the physical activity, specifically being outdoors when active and being active with friends, as something that made participating in physical activities more enjoyable, and thus pleasurable. Therefore, in some instances, being active in itself may not be perceived as fun and enjoyable, but the opportunities afforded when active may be. This may explain why being outdoors and with others was associated with valence, independent of levels of MVPA in Chapter 4.

Provides a Welcome Distraction

The most common reason participants described physical activity as calming in the current study is that the physical activity provided a distraction. Participants described how when they are active, they can focus solely on the activity and forget about stressors. This is consistent with the distraction hypothesis, which suggests that the "time out" from negative thoughts and stressors afforded by being physically active can yield improvements in mood (Morgan, 1985; Yeung, 1996). Previous research also found that adolescents perceived being physically active to be a more positive affective experience when it was an opportunity to focus on the activity and provided a distraction from other things going on in life (White, Olson, et al., 2018). Interestingly, researchers found that adolescents most commonly reported that distraction occurred during organised sport, potentially due to participants focusing more on what they are doing in these contexts (White, Olson, et al., 2018).

These results diverge from the results in Chapter 3 which showed that there was a positive within-person association between recreational physical activity and tense arousal. The results from the semi-structured interviews suggest that the positive within-person association between recreational physical activity and tense arousal may not reflect participants feeling more stressed or anxious during recreational physical activities. More likely, the positive within-person association between recreational physical activities and both tense and energetic arousal results from participants feeling a sense of excitement or feeling "supercharged" while recreationally physically active (Thayer, 1989). Therefore, although participants may feel tenser during recreational physical activities, this tension, in tandem with feeling more energised, may not necessarily be a negative experience for adolescents, and may be perceived as moderately positive (Thayer, 1989).

Physiological And Psychological Benefits of Getting Moving

The most discussed reason participants described physical activities as energising was that getting up and moving gave them a burst of energy. This supports the results from Chapter 4, which showed that overall MVPA had a significant positive within-person association with energetic arousal. However, results from Chapter 3 showed that participating in recreational physical activities has the strongest association with energetic arousal. This may be because participants completed recreational physical activities at a higher intensity than other physical activity domains. Breaking up sedentary behaviours with more vigorous activities is associated with larger increases in energetic arousal, and single breaks of higher intensity may be the most beneficial (Giurgiu et al., 2020). However, some participants also discussed how more intense physical activities make them feel more tired, indicating that there may be a non-linear association between physical activity intensity and energetic arousal.

Participants also discussed how experiencing positive psychological changes during physical activity made participating in physical activity more pleasurable and calming. For example, participants described how experiencing an endorphin high or a burst of adrenaline made the physical activity more pleasurable. Additionally, some participants discussed the sense of reward that they got from moving their body. This is similar to the results of multiple previous studies, which found that adolescents reported a more positive affective experience when they felt a sense of achievement from being active (Stych & Parfitt, 2011; White, Olson, et al., 2018). Some participants also described a boost in endorphins as something that made physical activities calming. In contrast, others discussed physical activities that allowed them to relax and release stress made them feel calmer. This is consistent with previous work that found that female undergraduate students held more favourable affective beliefs towards physical activities perceived to provide an opportunity for stress relief and relaxation (Ruissen et al., 2019).

Strengths and Limitations

A key strength of this study is that it was the first to simultaneously examine factors that influence experiences of valence, energetic arousal, and tense arousal during physical activities. Another strength of this study is that it asked participants about their affective experience during physical activities in daily life, rather than during physical activities in a controlled laboratory setting or anticipated future affect. However, a weakness of this study is that participants were asked to recall past experiences, which could potentially be influenced by recall bias. Additionally, there was a low response rate, meaning that the sample may not represent the larger sample who participated in the EMA study. For example, the adolescents who agreed to participate in an interview were highly active. Therefore, the interview participants may experience physical activity differently than less active adolescents. Lastly, the semi-structured interviews were conducted during COVID-19 lockdowns, whereas the EMA study was conducting before COVID-19. Participants' physical activity experiences may have differed substantially during the COVID-19 lockdown than before restrictions were implemented, meaning that the results from the quantitative and qualitative studies may not be directly comparable.

Conclusion

This study demonstrates that different factors may promote more positive valence, more energetic arousal, and less tense arousal whilst participating in physical activities. Therefore, it is unlikely that all physical activities will be associated with favourable affective outcomes. It is essential to consider potentially salient factors when considering the association between physical activity and affect in daily life. These include whether the physical activity is fun and enjoyable, whether adolescents have control over the activity, the physical and social contexts of the physical activity, whether the physical activity provides a distraction from stressors, and whether the activity leads to positive physiological and psychological outcomes.

Chapter 6: Adolescents' Daily Physical Activity and Subjective Wellbeing: An Examination of Direct and Mediated Associations

This chapter has been adapted from:

Bourke M., Hilland, T. A., & Craike, M. (2021). Daily physical activity and satisfaction with life in adolescents: an ecological momentary assessment study exploring direct associations and the mediating role of core affect. *Journal of Happiness Studies.* https://doi.org/10.1007/s10902-021-00431-z

Introduction

In addition to understanding the acute momentary association between physical activity and affect, it is important to consider how participation in physical activity over longer periods, such as over a day or regular levels of physical activity, is associated with subjective wellbeing in adolescents. Subjective wellbeing is made up of two key components, how satisfied an individual is with their life and their underlying incidental affective state (Diener, 1984; Diener, Emmons, Larsen, & Griffin, 1985). Although most adolescents experience moderate-to-high levels of subjective wellbeing, ratings of subjective wellbeing decline significantly during adolescence (Goldbeck et al., 2007; González-Carrasco et al., 2017; Tomyn & Cummins, 2011b). Conversely, incidences of common mental disorders, including depression and anxiety, become more prevalent during adolescence (Merikangas et al., 2010; Whiteford et al., 2013). Therefore, it is important to determine whether physical activity can promote subjective wellbeing during adolescence and protect against a decline in wellbeing.

Results from Chapter 3 indicated that adolescents who participate in greater recreational physical activity on average report experiencing more positive valence, feeling more energetic, and feeling less tense on average. Although these results indicate that there is a between-person relationship between recreational physical activity and incidental affect, they do not show whether there is a within-person association between daily physical activity and daily incidental affect (i.e., do adolescents experience more favorable affect throughout the day on days when they are more physically active than usual?). It is important to note that the acute within-person association between physical activity and integral affect (i.e., affect experienced during or immediately following participation in physical activity), may differ in magnitude and even direction to the within-person association between physical activity and incidental affect examined over longer periods of time (Koch et al., 2020; Reichert et al., 2017). Additionally, the results from previous chapters only explain the association between physical activity and affect, and do not explain the association between physical activity and satisfaction with life. Physical activity may also act as a time-invariant (i.e. between-person) or time-varying (i.e. within-person) predictor of satisfaction with life (Maher et al., 2013).

Results from a systematic review have highlighted that between-person associations between physical activity and components of subjective wellbeing in children and adolescents (Rodriguez-Ayllon et al., 2019). Multiple studies have also demonstrated that young adults recall more positive affect (Flueckiger et al., 2014; Flueckiger et al., 2017; Hyde et al., 2011), and less negative affect, on days during which they are more physically active than usual (Flueckiger et al., 2017). Similarly, multiple studies have shown that young adults report more positive perceptions of satisfaction with life on days during which they were more active (Maher et al., 2014; Maher et al., 2013; Maher et al., 2015). However, fewer studies have examined the within-person association between daily physical activity and daily incidental affect in adolescents (Gawrilow et al., 2013; Langguth et al., 2016). Additionally, to the author's knowledge, no studies have examined the within-person association between daily physical activity and satisfaction with life in a sample of adolescents.

In addition to the direct within- and between-person association between physical activity and components of subjective wellbeing, it has been hypothesised that core affect may mediate the association between physical activity and satisfaction with life (Elavsky et al., 2005; Lubans et al., 2016). This is consistent with empirical models, which show that affect is a distinct lower-order construct that influences cognitive evaluations of satisfaction with life (Blore et al., 2011; Tomyn & Cummins, 2011a). However, to the author's knowledge, no studies have examined whether affect mediates the within-person or between-person association between physical activity and satisfaction with life in adolescents.

Therefore, this study aims to determine to what extent daily physical activity is associated with daily satisfaction with life and incidental affect, and whether this relationship between physical activity and satisfaction with life is mediated by incidental affect. To achieve this aim, this study will answer the following research questions: 1) To what extent is daily physical activity related to daily satisfaction with life and incidental affect? 2) To what extent does incidental affect mediate the association between physical activity and satisfaction with life? It is hypothesized that adolescents will be more satisfied with their life and experience more positive incidental effect on days when they are more physically active than usual. Additionally, it is hypothesised that adolescents who are more physically active than others on average will be more satisfied with their life and report more positive incidental affect on average. It is also hypothesised that incidental affect will mediate the within- and between-person association between daily physical activity and satisfaction with life.

Methods

Participants

Participant recruitment is described in detail in Chapter 3. Briefly, participants were adolescents aged 13-17 years living in an urban or suburban area of Melbourne with a mobile phone with access to the internet. Written informed assent was sought from each participant in addition to written parental consent (Appendix C). The study procedures were approved by Victoria University Human Research Ethics Committee (Appendix D).

Procedures

This study used a combination of EMA and daily diaries to collect data over four days (Thursday-Sunday). EMA procedures are described in detail in Chapter 3. In addition to the EMA procedures, participants completed a daily diary each evening at 8:30pm. Responses to daily diaries were included if participants completed them before midnight on the evening the diary was sent.

Measures

An overview of self-reported measures participants responded to when completing the daily diary each evening can be seen in Appendix I.

Device-Measured Physical Activity

Levels of device-measured physical activity were measured using the ActiGraph GT3X+ (ActiGraph LLC, Pensacola, FL, USA). The device was positioned on top of the participants' dominant wrist and attached with a nylon strap. Participants were instructed to wear the accelerometer at all times except when they were sleeping, during water-based activities, when participating in activities where wearing accessories was prohibited, or during activities where there was a risk that wearing the accelerometer could result in injury or damage to the device. Participants were sent a text message at 7:30 am each morning reminding them to wear their accelerometer.

Raw movement data were downloaded from the vertical axis in 5-second epochs using Actilife version 6.12.1 (ActiGraph LLC, Pensacola, FL, USA). Data were classified according to the cut points developed by Crouter et al. (2015) of 432-4320 counts per minute for light intensity physical activity, 4321-13,548 counts per minute moderate intensity physical activity and greater than 13,548 counts per minute for vigorous intensity physical activity. Additionally, overall device measured physical activity was operationalised as any activity >431 counts per minute.

Accelerometer non-wear time was defined using well-established guidelines as any interval of at least 60 consecutive minutes with zero counts, allowing for spikes for up to 2-minutes in activity counts between 0-100 counts per minute (Troiano et al., 2008). Only days with at least eight hours of wear time between 4:00am and 8:30pm were considered valid and included in the analyses. The cut-off of 8:30pm was used as this is when the link to the daily diary was sent. The cut-off of 4:00am onwards was used to avoid physical activity that may have been accumulated after midnight but before participants went to bed the night before. Participants were only included in analyses if they had at least three days (including one weekend day) of valid accelerometer data. Research has shown that three days provides reliable estimates (R = 0.7) (Mattocks et al., 2008), and leads to greater inclusion and less bias in adolescent populations than more stringent inclusion criteria (Smith et al., 2017).

Self-Reported Physical Activity

Participants self-reported daily levels of physical activity in three domains: transportation, leisure-time, and housework using an adapted version of the International Physical Activity Question for Adolescents (IPAQ-A; Hagströmer et al., 2008). The IPAQ-A was adapted for this study to measure daily levels of physical activity rather than weekly levels of physical activity. Total minutes spent in MVPA in each of these domains each day was calculated. Only participants who reported domain-specific levels of physical activity on at least three days were included in analyses.

Satisfaction with life

Satisfaction with life was measured each evening using a single validated item (Jovanović, 2016), modified to measure daily life satisfaction. Similar modifications to measure state, rather than trait, satisfaction with life has been applied in other studies (Jayawickreme et al., 2017b; Maher et al., 2014). Participants responded to the question "all things considered, how satisfied are you with your life as a whole today?" on a 10-point sliding scale from 1 (not at all satisfied) to 10 (completely satisfied).

Daily Incidental Affect

Participants' core affect was measured at each EMA prompt and when participants completed the daily diary each evening. The measure of core affect is described in detail in Chapter 3. Briefly, participants’ core affect at each prompt were measured using a short scale, developed specifically for ambulatory monitoring of core affect in everyday life (Wilhelm & Schoebi, 2007). Valence was measured using two items with anchors of discontent-content and unwell-well; energetic arousal was measured using two items with anchors of tired-awake and unenergetic-energetic; and tense arousal was measured using two items with anchors of calm-agitated and relaxed-tense. Daily incidental affect was calculated for each of the three dimensions of affect as the average reported across all the completed assessments in a day. Scores were only calculated on days where participants completed at least three assessments of affect across the entire day. At the daily level, the within-person reliabilities for valence, energetic arousal, and tense arousal were 0.14, 0.66, and 0.76, respectively. The between-person reliabilities were 0.79, 0.88, and 0.95, respectively. Given the low within-person reliability for valence, the within-person results for valence may be unreliable and should be interpreted with extreme caution.

Demographics

Participants reported their age, sex, and postcode. Postcode data was used to determine each participant’s SEIFA (Australian Bureau of Statistics, 2016).

Data Analysis

Data were screened for missingness, and compliance rates were calculated. Logistic regression was used to determine whether participants included in the analyses differed from those not included in analyses in terms of age, sex and area-level socio-economic status. Descriptive statistics were calculated for participants included in the analyses.

Bivariate within-person and between-person associations between each of the study variables were estimated. Within-person associations were estimated using repeated measures correlation (Bland & Altman, 1995a) with the rmcorr package in R (Bakdash & Marusich, 2017). The rmcorr package estimates the common intra-individual association between two variables using atypical application of ANCOVA where the participant is treated as the factor to statistically adjust for inter-individual variance (Bakdash & Marusich, 2017). Results are calculated as the square root of partial eta-squared based on the variance of the measure treated as a covariate in the ANCOVA and the residual variance, which is bounded between -1 and 1 and represents the strength of the linear association between two variables (Bakdash & Marusich, 2017). For between-person associations, the average of repeated measures for each participant was calculated, and the correlation between these averages of two variables was estimated (Bland & Altman, 1995b). Between-person correlations were estimated in SPSS (IBM). For correlation analyses, to account for differences in accelerometer wear time, daily minutes of device-measured physical activity were converted to a percentage of daily accelerometer wear-time. Before estimating correlation coefficients, each variable was inspected for normality through visual inspection of Q-Q plots and histograms, and computing skewness scores. Variables with an absolute value of skewness greater than +1.5 or less than -1.5 were considered non-normally distributed (Tabachnick & Fidell, 2013), and transformed using a natural logarithm.

Finally, to test whether core affect (i.e. valence, energetic arousal, or tense arousal) mediated the association between physical activity (i.e. device measured intensity specific physical activity and self-reported domain specific physical activity) and satisfaction with life, multilevel mediation models were estimated using the MLmed macro (Rockwood, 2017) for SPSS (IBM). The MLmed macro simultaneously estimates within-person and between-person direct and indirect effects (Figure 6.1) by person mean and grand mean centering predictor variables (Enders & Tofighi, 2007) . The significance of indirect effects was estimated as 95% Monte Carlo confidence intervals based on 10000 resamples. Mediation models were estimated where a physical activity variable had a significant correlation with a mediator variable (i.e. valence, energetic arousal, or tense arousal) and the mediator variable had a significant correlation with satisfaction with life (Shrout & Bolger, 2002). Each model was estimated with random intercepts and fixed slopes. Additionally, models where device-measured physical activity was the independent variable controlled for accelerometer wear time. Equations for each of the mediation models can be seen in Appendix J.

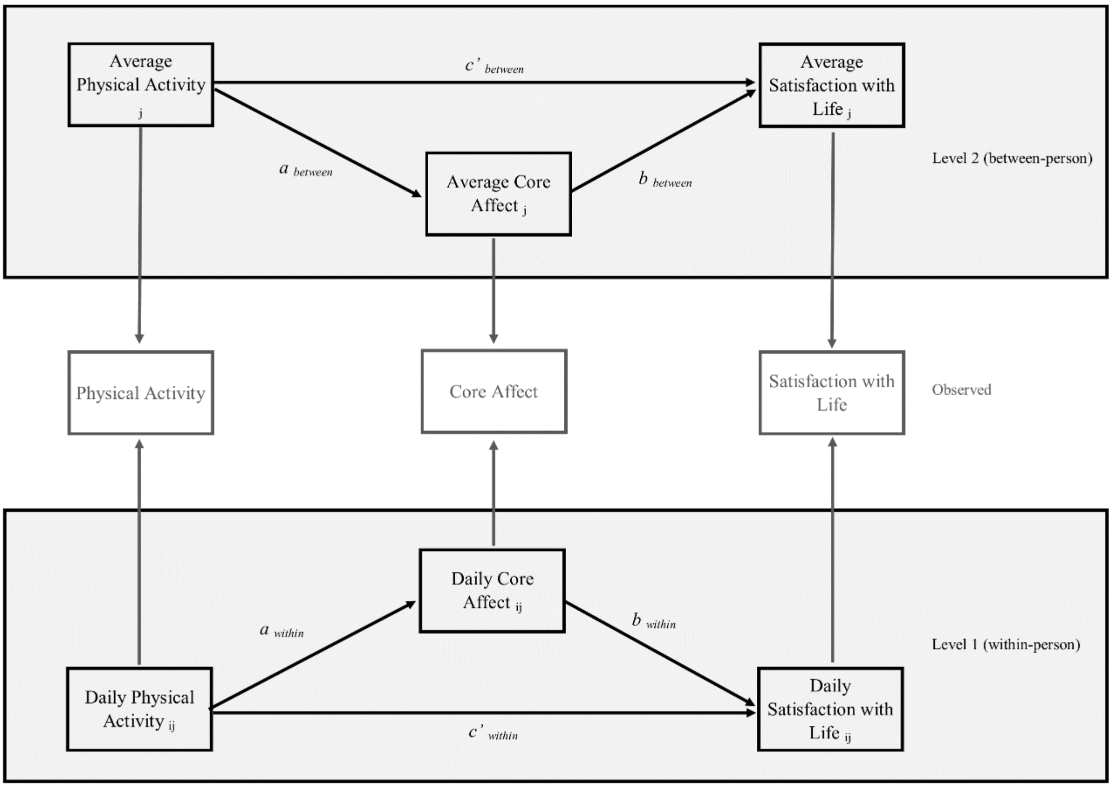

Figure 6.1 Schematic of the within-person and between-person mediation models between physical activity (i.e. device-measured or self-reported physical activity), core affect (i.e. valence, energetic arousal, or tense arousal) and satisfaction with life.

Results

Compliance

Out of a possible 476 diary entries, participants completed a total of 394 diary entries (82.8% compliance rate). Of these, 313 could be matched with valid accelerometer data. However, only 69 of the 119 participants (58.0%) had diary data and valid accelerometer data for at least three days, totaling 245 observations. Of the participants with at least three days of valid accelerometer data, 72.5% had data for all four days. For self-reported physical activity, 94 participants (79.0%) had diary data on at least three days, totaling 351 observations. Of the participants with at least three days of self-reported data, 73.4% provided data on all four days. The average compliance rate of ecological momentary assessment prompts for participants with valid diary data on at least three days was 65.4% (SD = 18.9%).

Descriptive statistics

Descriptive statistics for the 94 participants who provided diary data on at least three days can be seen in Table 6.1. Females were more likely to have at least three days of data than males (OR = 3.76, 95% CI = 1.38 to 10.25, $p = .010$), as were older participants (OR = 1.58, 95%CI = 1.15 to 2.16, $p = .005$). The likelihood of having valid data on at least three days did not differ according to area-level socioeconomic status.

Table 6.1 Participant demographics and means, standard deviations, and intraclass correlation coefficients (ICC) of study variables

	Mean	Standard Deviation	ICC
Gender (% female)	54.3%	-	-
Age	14.43	1.30	-
SEIFA Index	1030.02	56.95	-
Overall device measured physical activity (mins·day^{-1})	348.28	91.81	0.27
Device-measured light intensity physical activity (mins·day^{-1})	240.79	60.34	0.22
Device-measured moderate intensity physical activity (mins·day^{-1})	99.27	44.22	0.36
Device-measured vigorous intensity physical activity (mins·day^{-1})	8.24	9.68	0.20
Self-reported leisure-time physical activity (mins·day^{-1})	62.70	86.27	0.22
Self-reported active travel (mins·day^{-1})	27.05	40.46	0.19
Self-reported household physical activity (mins·day^{-1})	16.71	38.40	0.06
Satisfaction with life	7.95	1.56	0.38
Average daily valence	11.03	1.76	0.66
Average daily energetic arousal	8.79	2.27	0.53
Average daily tense arousal	4.89	1.70	0.62

Within-Person and Between-Person Correlations Between Physical Activity, Incidental Affect, and Satisfaction with Life

The within- and between-person correlations between physical activity, incidental affect, and satisfaction with life are displayed in Table 6.2. Results showed significant within-person correlations between daily device-measured light-intensity and moderate-intensity physical activity with daily satisfaction with life. This indicates that participants were more satisfied with their life on days that they participated in more minutes than usual of light- and moderate-intensity physical activities during the day. Results showed that daily levels of device-measured overall physical activity, device-measured vigorous-intensity physical activity, and daily levels of all domains of the self-reported physical activities did not have a significant within-person association with satisfaction with life. Additionally, results showed that there were no within-person correlations between any physical activity variable and incidental affect.

There was a significant between-person correlation between average levels of daily self-reported leisure-time physical and average levels of daily satisfaction with life. This suggests that those participants who reported engaging in more minutes of leisure-time physical activities on average, compared to other participants, reported feeling more satisfied with their life. Average levels of overall device-measured physical activity, light-, moderate- and vigorous-intensity device-measured physical activity, self-reported active travel and self-reported household physical activity did not have a between-person correlation with satisfaction with life.

There were also significant between-person correlation between device measured vigorous-intensity physical activity and self-reported leisure-time physical activity with energetic arousal. This suggests that participants who reported engaging in more minutes of leisure-time physical activities on average, and participants who participated in greater levels of vigorous-intensity physical activity on average, compared to other participants, reported feeling more energetic throughout the day on average. Average levels of overall device-measured physical activity, light- and moderate-intensity device-measured physical activity, self-reported active travel and self-reported household physical activity did not have a significant between-person correlation with energetic arousal. No physical activity variables had a significant between-person correlation with valence or tense arousal.

Table 6.2 Overview of within-person and between-person correlations between physical activity, incidental affect, and satisfaction with life

	1	2	3	4	5	6	7	8	9	10	11
1. Daily overall device measured physical activity	-	.88**	.87**	.33**	-.19	-.02	.04	.18	.15	.14	-.18
2.Daily device-measured light intensity physical activity	.87**	-	.55**	.03	-.13	.00	.03	.21	.23	.12	-.23
3. Daily device-measured moderate intensity physical activity	.84**	.49**	-	.37**	-.23	-.03	-.03	.08	-.01	.05	-.06
4. Daily device-measured vigorous intensity physical activity [a]	.35**	.02	.51**	-	.17	-.15	.18	.08	.06	.25*	-.02
5. Daily self-reported leisure time physical activity [a]	.14	-.01	.22**	.33**	-	.02	.06	.31**	.19	.29**	-.08
6. Daily self-reported active travel [a]	.17*	.15*	.16*	.01	.11	-	.02	.05	-.06	-.16	.09
7. Daily self-reported household physical activity [a]	-.07	-.12	-.02	.11	.06	-.15*	-	.12	-.04	.03	-.07
8. Daily satisfaction with life	.22**	.18*	.21**	.01	-.03	.02	.10	-	.62**	.51**	-.54**
9. Daily valence	-.05	-.04	-.07	-.01	-.04	.03	.05	.44**	-	.63**	-.71**
10. Daily energetic arousal	-.05	-.09	.00	.13	.07	.07	.09	.38**	.57**	-	-.54**
11. Daily tense arousal	-.02	-.09	.06	.09	.11	-.07	.05	-.26**	-.55**	-.24**	-

* p<.05 ** p<.01
Correlation coefficients below the diagonal in the correlation matrix are within-person correlations, correlations above the diagonal in the correlation matrix are between person correlations.
[a] log transformed

Mediation Models

Results from the correlation table (Table 6.2) showed a significant between-person correlation between self-reported leisure-time physical activity and device-measured vigorous-intensity physical activity with energetic arousal. There were no other significant within-person or between-person correlations between any physical activity and core affect variables, so only two mediation models were estimated. A mediation model was estimated to determine whether energetic arousal mediated the between-person association between average levels of self-reported leisure-time physical activity and satisfaction with life (Figure 6.2). Results showed a significant indirect effect, and a non-significant direct effect, indicating that energetic arousal mediated the between-person association between leisure-time physical activity and satisfaction with life. A mediation model was also estimated to determine whether energetic arousal mediated the between-person association between average levels of device-measure vigorous-intensity physical activity and satisfaction with life (Figure 6.3). Again, results showed a significant indirect effect, and a non-significant direct effect indicating that energetic arousal mediated the between-person association between device-measured vigorous-intensity physical activity and satisfaction with life.

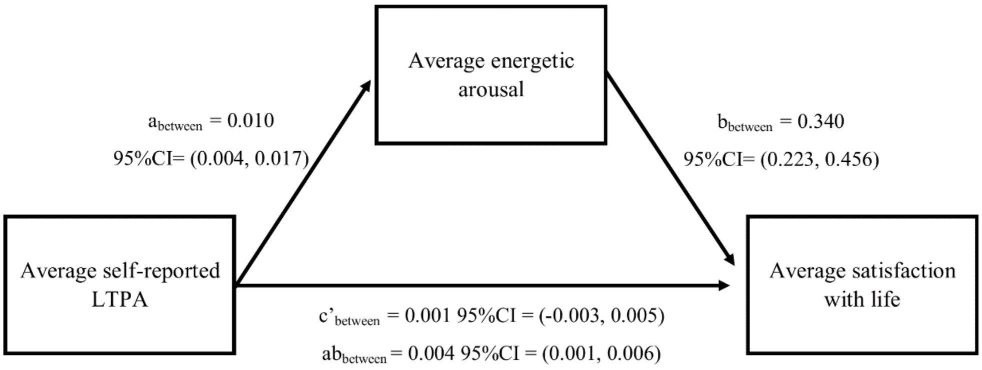

Figure 6.2 Mediation model for the between-person association between average daily self-reported leisure-time physical activity and average satisfaction with life mediated by average energetic arousal. $ab_{between}$ = indirect between-person effect, $c'_{between}$ = direct between-person effect.

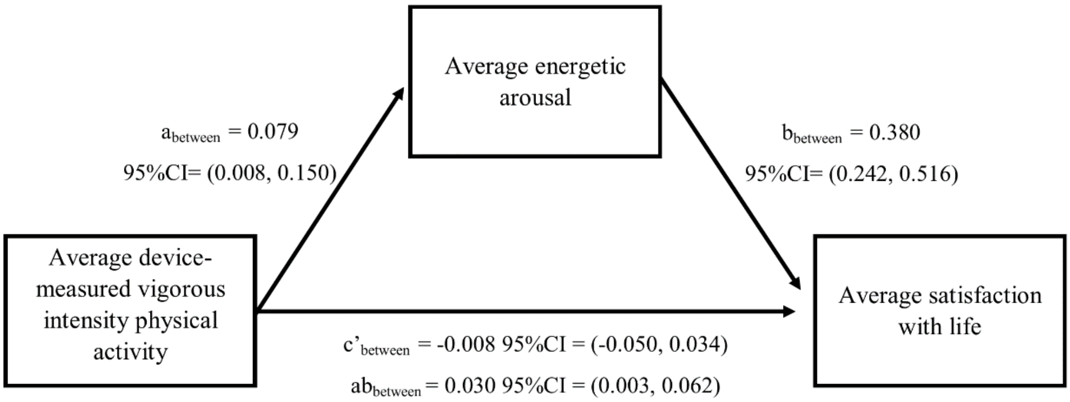

Figure 6.3 Mediation model for the between-person association between average device-measured vigorous intensity physical activity and average satisfaction with life mediated by average energetic arousal. $ab_{between}$ = indirect between-person effect, $c'_{between}$ = direct between-person effect.

Discussion

This study examined the within-person and between-person associations between physical activity, incidental affect, and satisfaction with life in adolescents. Additionally, this study examined whether daily incidental affect mediated the association between physical activity and satisfaction with life. In partial support of the study hypothesis, results showed that adolescents were more satisfied with their life on days when they accumulated more device-measured light-intensity and moderate-intensity physical activity than usual. Additionally, participants who reported participating in greater levels of leisure-time physical activity on average reported being more satisfied with their life on average. Not supporting the study hypothesis, results showed that adolescents did not report more positive incidental affect on days that they were more active than usual. However, in partial support of the study hypothesis, adolescents who participated in greater levels of vigorous-intensity physical activity on average and reported participating in greater leisure-time physical activity on average reported feeling more energetic throughout the day on average. Additionally, mediation analyses showed that energetic arousal mediated the association between average levels of self-reported leisure-time physical activity and device-measured vigorous intensity physical activity with satisfaction with life.

The results from the current study highlight the importance of encouraging physical activities throughout the day to promote satisfaction with life in young people. Previous researchers have pointed to the revitalizing effect of participating in physical activities as a factor that could explain the within-person association between physical activity and satisfaction with life (Maher et al., 2013; Maher et al., 2015). However, the results from the current study showed that energetic arousal did not mediate the within-person association between physical activity and satisfaction with life. Another potential mechanism explaining the association between moderate-intensity physical activity and satisfaction with life is contextual factors. Results from previous EMA studies have shown that adolescents are more likely to be with friends and outdoors when engaging in physical activity (Papini et al., 2020). Therefore, adolescents may feel more socially connected and be exposed to more green space when they are more physically active than usual, promoting positive perceptions of satisfaction with life (Jose et al., 2012; Vanaken & Danckaerts, 2018). It is also possible that physical activity, especially light-intensity physical activity, could be accumulated throughout the day incidentally whilst participating in other positive daily activities (e.g. completing other important tasks of daily life), or while pursuing personally important goals, which have a positive association with satisfaction with life in young people (Nezlek, 2005; Zuffianò et al., 2018). Therefore, the relationship between light-intensity daily physical activity and satisfaction with life may be an artifact of people participating in more light-intensity physical activity on days they complete other fulfilling activities. Further research is needed to determine whether the association between light-intensity physical activity and satisfaction with life remains when controlling for other positive daily events.

Although daily levels of overall, light-intensity and moderate-intensity device-measured physical activity were associated with satisfaction with life in the present study, daily levels of self-reported leisure-time physical activity did not have a significant within-person association with satisfaction with life, which is in contrast to previous research (Maher et al., 2013). However, the results from the current study showed that adolescents who reported engaging in more leisure-time physical activity than others on average were more satisfied with their life. This may be because adolescents who reported engaging in more leisure-time physical activity than others may have a more positive physical self-concept, self-esteem, and self-efficacy than those who are less active, which are potential mechanisms that may explain the association between physical activity and satisfaction with life (Elavsky et al., 2005; Lubans et al., 2016). Alternatively, it is unlikely that levels of physical self-concept, self-esteem, and self-efficacy vary from typical levels on the days that adolescents are more physically active than usual. Supporting this, the findings of a daily diary study involving adults found that the standardised mean difference in levels of self-efficacy between active and inactive adults (d = 0.38) was more than double the standardised mean difference of self-efficacy within-individual on days they were active and not active (d = 0.18) (Kangas et al., 2015). Additionally, a recent EMA study found only a small positive within-person association between physical activity and self-esteem in a sample of adolescents and young adults (Mazereel et al., 2021).

No significant between-person associations between average levels of self-reported active travel or household physical activity and satisfaction with life were observed in the current study. These findings are consistent with results from a cross-sectional study of university students, which found a positive association between self-reported leisure-time physical activity and satisfaction with life but no association between self-reported work, transport, or household physical activity and satisfaction with life (Pedišić et al., 2015). This may be because transport or household physical activities are less likely to promote positive self-concept in young people (Babic et al., 2014). This adds to research that has shown that the benefits of physical activity on wellbeing may be domain-specific (White et al., 2017), and further highlights the importance of encouraging leisure-time physical activity to promote mental health (Teychenne et al., 2020).

Although results showed significant within-person correlations between daily device-measured physical activity and satisfaction with life, daily physical activity did not have a significant within-person correlation with daily incidental affect. This differs somewhat from the results in Chapter 3 and Chapter 4, which showed that adolescents may feel more energetic, but also more tense, when physically active. However, this finding is consistent with previous studies which found that daily physical activities were not related to energetic or tense arousal throughout the day in young adults (Schöndube et al., 2016) or average pleasant and activated affect reported throughout the day in children (Kühnhausen et al., 2013). This may be that that acute improvements in affect as a result of participating in physical activity may be short lived, with the within-person association between physical activity and affect being strongest during or immediately following participation in physical activity and dissipating over time (Wichers et al., 2012).

Results showed that daily device measured vigorous-intensity physical activity and self-reported leisure-time physical activity had a significant between-person correlation with energetic arousal. However, there were no significant between-person correlations between physical activity and valence and tense arousal. This is consistent with results from multiple recent meta-analysis, which showed that physical activity has a significant positive association with positive activated affect but was not associated with negative activated affect (Buecker et al., 2020; Wiese et al., 2018). Interestingly, the results regarding the between-person association between leisure-time physical activity and affect differed from those in Chapter 3, which found that adolescents who participated in recreational physical activities more often than others reported more positive valence, greater energetic arousal, and less tense arousal on average. However, the direction of the between-person correlation between leisure-time physical activity and valence and tense arousal mirrored those reported in Chapter 3 for recreational physical activities. Therefore, it is possible that the null finding for leisure-time physical activity is a result of this study having fewer participants meeting the requirements to be included in the analysis, and therefore having lower power to detect an association.

In addition to the independent associations between physical activity and satisfaction with life, results indicated that energetic arousal mediated the association between average levels of self-reported leisure-time physical activity and satisfaction with life. Adolescents who reported more leisure-time physical activity on average also reported feeling more energetic throughout the day on average, and in turn, they reported being more satisfied with their life. Past research has also shown that adolescents who are more active on average than other adolescents report feeling less tired throughout the day (Dunton et al., 2014). Therefore, it is likely that adolescents who participate in greater leisure-time physical activity than other adolescents experience more vitality during the day. Thus, more active adolescents may have a greater ability to pursue individual goals and participate in positive daily events, which could be positively associated with satisfaction with life.

Mediation analyses also showed that although average levels of device-measured vigorous-intensity physical activity were not directly associated with satisfaction with life, there was an indirect association between average levels of vigorous-intensity physical activity and satisfaction with life through energetic arousal. Adolescents who participated in more vigorous-intensity physical activity on average than other adolescents reported feeling more energetic throughout the day and, in turn, felt more satisfied with their life. These findings are consistent with results from previous research, which has found a significant cross-sectional association between device-measured vigorous-intensity physical activity, but not light or moderate-intensity physical activity, and incidental affect in adolescents (Costigan et al., 2019). It also adds to the extant literature, which shows that adolescents who participate in high-intensity exercises may experiences improvements in well-being over time (Leahy et al., 2020).

The results from the current study have some important implications. To improve daily satisfaction with life, it may be more efficacious to increase incidental physical activity that can be performed while completing other personally important activities. Other physical activities such as vigorous-intensity physical activity and purposeful leisure-time physical activity may be participated in independently of any other fulfilling activities. They, therefore, may not have a short-term impact on perceptions of satisfaction with life. However, considering the long-term impact of regular exercise on life satisfaction, more purposeful leisure-time physical activity may be more efficacious at improving perceptions of satisfaction with life. Additionally, more vigorous physical activities that may improve young people's vitality may also positively impact satisfaction with life in the long term. Therefore, promoting both incidental physical activity during other daily activities and more purposeful leisure-time and vigorous-intensity physical activities could positively impact adolescents' perceptions of satisfaction with life.

The current study adds to our understanding of the associations between physical activity, incidental affect, and satisfaction with life in adolescents; however, some limitations must be considered. First, domain-specific physical activity was measured with self-report, which may overestimate physical activity (Hagströmer et al., 2008). Additionally, self-reported measures may be influenced by affective states and cognitive biases that may also affect perceptions of mental health (Choi et al., 2019). Therefore, it is possible that these cognitive biases could influence the association between self-reported physical activity and satisfaction with life and may explain why associations differed between self-report and device-measured physical activities. Secondly, because EMA was used in addition to daily diaries, to reduce participant burden, data collection only occurred over four days. Although assessing core affect in the moment rather than having participants recall daily affect was a strength of the current study and meant that the measure of affect was purely affective rather than cognitive, it did mean that the study period was shorter than typical daily diary studies. However, participants were only included in analyses if they had at least three days of valid physical activity data, including at least one weekend day, and the majority of participants that were included in the analyses had data on all four days. Additionally, the ICC for satisfaction with life, physical activity, and affect in the current study were similar to previous studies, indicating similar levels of within-person variability in each of these variables compared to previous studies (Haas et al., 2017; Maher et al., 2014; Maher et al., 2013; Maher et al., 2015). Together, this increases confidence that accurate estimates of within-person and between-person associations could be estimated. Nevertheless, the short duration may attenuate associations at the within-person level of analysis because not enough within-person variation in physical activity and affect may have been captured. Third, although compliance with the daily diary was acceptable, compliance with ecological momentary assessment and accelerometer procedures was less favorable. This meant that 42% of participants were excluded from analyses for device-measured physical activity. Lastly, the within-person reliability of the valence subscale was extremely low meaning that the within-person correlations estimated for valence are unlikely to be reliable.

Conclusion

Results indicated that adolescents are more satisfied with their life on days that they participated in greater levels of device-measured overall, light-intensity and moderate-intensity physical activity than usual. Additionally, adolescents who reported participating in greater levels of leisure-time physical activity on average were more satisfied with their life. Results also showed that participants who participated in greater levels of self-reported leisure time and device measured vigorous-intensity physical activity on average reported feeling more energetic on average. Additionally, there was a mediated association between self-reported leisure time and device measured vigorous-intensity physical activity with satisfaction with life through energetic arousal. Given adolescence is a time of life where ratings of satisfaction with life decline, these results highlight the potential efficacy of encouraging participation in physical activity during adolescence to promote subjective wellbeing.

Chapter 7: General Discussion

Overview of Results

The overarching objective of this thesis was to investigate the factors that influence the association between physical activity and components of wellbeing. To achieve this objective this thesis had four aims: 1) determine to what extent the within-person and between-person association between MVPA and affect differs between distinct domains of physical activity; 2) determine the extent to which the physical environment and social context influence the within-person association between MVPA and affect in adolescents' daily lives; 3) qualitatively investigate adolescents' perceptions of factors that are related to experiencing more positive affect during physical activity and 4) determine to what extent daily physical activity is associated with daily satisfaction with life and incidental affect, and whether the relationship between physical activity and satisfaction with life is mediated by incidental affect.

Considering the first aim, results showed that there was a significant favourable between-person association between recreational physical activity and valence, energetic arousal, and tense arousal. Neither active travel nor household physical activity had a significant between-person association with any of these outcomes. Findings also revealed that recreational physical activity had a significant positive within-person association with energetic arousal and tense arousal. Active travel and household physical activity did not have a significant within-person association with these outcomes, whereas no domains of physical activity had a significant within-person association with valence.

For the second aim, results showed that the physical environment and social context of physical activities may influence the within-person association between physical activity and affect. Being outdoors had a positive within-person association with valence and energetic arousal, indicating that there may be some added benefits associated with being physically active outdoors. Additionally, findings indicated that there was a synergistic effect between MVPA and being outdoors on tense arousal. When participants were more active than usual outdoors, they reported feeling less tense, whereas when more active than usual indoors, participants reported feeling tenser. Considering the social context, being with someone had a positive within-person association with energetic arousal independent of levels of physical activity. However, being alone or with someone else was not associated with valence or tense arousal and did not have a synergistic effect with MVPA on affect.

With regards to the third aim, results from the qualitative component of this thesis provided further insights into factors that may influence the within-person association between physical activity and affect in adolescents' daily lives. Participants discussed several factors that are likely to influence the acute relationship between physical activity and affect. Finding activities fun and enjoyable, having control over the activities, completing the activities outdoors, and perceiving positive psychological benefits from getting moving were identified as factors that made participating in physical activities more pleasurable. Additionally, some participants described how they found participating in physical activities with others more pleasurable, whereas others described pleasurable physical activities as ones that they participated in alone. For energetic arousal, participants described perceived physiological benefits of getting moving, being outdoors when active, and the physical activity providing a distraction as factors that contributed to participating in physical activities being energizing. For tense arousal, participants described the physical activity providing a distraction, being outdoors when active, the activity being fun and enjoyable, being active alone, and the perceived psychological benefits of getting moving as factors that made being physically active more calming.

Concerning the fourth aim, results showed that adolescents were more satisfied with their life on days when they accumulated more device-measured overall, light-intensity, and moderate-intensity physical activity than usual. However, daily physical activity was not associated with daily incidental affect. Additionally, adolescents who reported engaging in more leisure-time physical activity on average were more satisfied with their life and reported more energetic arousal on average. Adolescents who participated in greater levels of device-measured vigorous-intensity physical activity also reported feeling more energetic on average. Results from mediation analyses showed that self-reported leisure-time physical activity and device-measured vigorous intensity physical activity were indirectly associated with satisfaction with life through energetic arousal.

Policy Implications

The results from this study show that the between-person association between physical activity and wellbeing is likely domain specific. Results from Chapter 3 showed that only recreational physical activities had a between-person relationship with affect while results from Chapter 6 showed that only self-reported leisure-time physical activity had a significant positive between-person association with satisfaction with life. This is consistent with previous research in young people which indicated that leisure-time physical activity may be more favourably associated with affect and satisfaction with life (Pedišić et al., 2015; White, Parker, et al., 2018).

These results have some potential public health implications. Despite results from the current study suggesting that the relationship between physical activity and wellbeing may be domain specific, global physical activity guidelines for public health suggest that children and adolescents should accumulate an average of 60 minutes of MVPA per day, regardless of the domain in which it occurs (Bull et al., 2020). Although these guidelines are based on extensive evidence for a broad range of health outcomes, evidence of the association between physical activity and mental health is far less abundant than that for adiposity and cardiometabolic health in children and adolescents (Chaput et al., 2020). Therefore, although the extant literature shows that adherence to these guidelines has a positive association with various physical health outcomes in adolescents, it is less clear whether meeting these guidelines is associated with mental health in youth (Poitras et al., 2016). Additionally, when developing the global physical activity guidelines for children and adolescents, it was determined that there was insufficient evidence to establish whether the association between physical activity and health was domain specific (Chaput et al., 2020). Nevertheless, there is a growing body of evidence which indicates that the association between physical activity and mental health may be domain specific (White et al., 2017). Consequently, there have been calls for physical activity guidelines specifically for mental health in adults, with a focus on leisure time physical activities, physical activities that are enjoyed, and physical activities that are autonomous (Teychenne et al., 2020). Based on the results from this thesis, similar guidelines in adolescents have merit.

Message framing of physical activity guidelines may also have the potential to maximize their impact (Milton et al., 2020). In their scoping review Williamson et al. (2020) suggest that messaging should focus on the acute affective benefits of participating in physical activity for children and adolescents. Not only does using affective messaging lead to greater increases in overall and leisure-time physical activity in young people (Morris et al., 2016; Sirriyeh et al., 2010), it may potentially lead to young people participating in more intrinsically motivated physical activities in their leisure time which could promote mental health. However, the public messaging for the most recent global physical activity guidelines employs the tagline "Every Move Counts" (Figure 7.1). Although this message is consistent with the guidelines, specific messaging for the mental health benefits of participation in recreational physical activities should be considered.

Figure 7.1 Screen shot of the World Health Organization's "Every Move Counts" campaign. Available from https://www.youtube.com/watch?v=jY7YvglA92s&ab_channel=WorldHealthOrganization%28 WHO%29

Implications for Future Research

Disaggregating the Within-Person and Between-Person Association Between Physical Activity and Wellbeing

The results from this thesis highlight the importance of disaggregating the within-person and between-person associations between physical activity and wellbeing. Specifically, results from Chapter 3 showed that the relationship between recreational MVPA with valence and tense arousal were different, and even in the opposite direction for tense arousal, at the within-person and between person levels of analysis. Additionally, results from Chapter 6 showed that different forms of physical activity were associated with satisfaction with life at the within-person and between-person levels. These results highlight how only examining the relationship between physical activity and wellbeing at the between-person level may lead to ecological fallacies about this relationship (Dunton, 2017; Reichert et al., 2020). For example, if only examining the between-person association between recreational MVPA and affect, researchers may falsely conclude that because people who are more active feel less tense, people will feel less tense when they are more physically active than usual. Additionally, as shown in Chapter 6, if only examining between-person associations between physical activity as satisfaction with life, researchers may conclude that engaging in light and moderate intensity physical activity is not beneficial. However, examining the association at the within-person level clearly shows that there are benefits to engaging in more light- and moderate-intensity physical activity on satisfaction with life.

Disaggregating the within-person and between person associations between physical activity and wellbeing elucidates both the short-term benefits of participation of physical activity on wellbeing and the enduring differences in wellbeing between individuals who are more and less active (Dunton, 2017). This has potential to shed light onto the complexities of the relationship between physical activity and wellbeing and provide insights into different mechanisms that may operate at the within-person and between-person levels, which has implications on the development of theories and interventions (Dunton, 2017). Furthermore, researchers may explore process-by-person interactions, that is, to examine how within-person association differ between individuals (Russell & Gajos, 2020). Doing so can inform tailored interventions which may have the potential to contribute to the greatest improvements in physical activity and wellbeing of specific subgroups of young people.

Measurement of Affect in the Context of Physical Activity

Results from Chapters 3 and 4 showed that although MVPA may have a within-person association with arousal, it does not appear to have an association with valence. Although this could have been a result of the valence subscale having a low within-person reliability, this could also potentially explain findings from previous EMA studies which found that MVPA had a within-person association with positive affect but not negative affect. Positive affect is conceptualized as a combination of high arousal and positive valence, while negative affect is conceptualized as a combination of high arousal and negative valence (Watson & Tellegen, 1985). Therefore, increases in activation, even without changes in valence, could be associated with increases in positive affect. Additionally, if activation increased or remained stable, negative affect would only decrease with a positive shift in valence. Additionally, tense arousal is highly correlated with negative affect (Watson et al., 1999), and are positioned at similar places on the affective circumplex (Yik et al., 1999). Given the results in this thesis showed that adolescents reported more tense arousal when participating in greater levels of recreational MVPA than usual, this provides further evidence that MVPA in daily life is unlikely to have an inverse within-person association with negative affect in young people.

Undoubtedly, there are a multitude of theoretical perspectives that can be taken with regards to the measurement of affect in the context of physical activity (Ekkekakis & Zenko, 2016). There is clearly no one best way to conceptualize affect in the context of physical activity, and different approaches will have unique advantages and limitations (Ekkekakis & Petruzzello, 2000). However, the near ubiquitous use of the concepts from the rotated circumplex model in the study of the association between physical activity and affect in adolescents' daily lives makes it difficult to disentangle the effects of physical activity on valence and arousal. Given that experimental research has shown that physical activity may have opposing effects on valence and arousal (Benjamin et al., 2012; Malik et al., 2018, 2019), examining these dimensions separately in adolescents daily life may provide unique insights into the association between physical activity and affect. Although a three-dimensional model of affect (Leonhardt et al., 2016) was used in this thesis, some researchers have suggested to achieve a finer grained and more structurally valid representation of the affect circumplex, measures should tap into octants of the affect circumflex (Larsen & Diener, 1992), or even utilize a 12-point affect circumplex (Yik et al., 2011). However, adding dimensions may have diminishing returns with regards to the amount of variance explained while adding considerable complexity to the measurement of affect (Ekkekakis & Petruzzello, 2002), while also increasing respondent burden. Therefore, measuring two or three dimensions of valence and activation may provide a parsimonious reflection of the entire affect circumplex. Researchers could employ the use of single item measures of affect including the Feeling Scale (Hardy & Rejeski, 1989) and the Felt Arousal Scale (Svebak & Murgatroyd, 1985), such as is common in experimental studies of the association between physical activity and affect. Using single item measures also allow researchers to implement variations of traditional EMA studies, such as micro-EMA studies which can decrease participant burden, and increase compliance despite an approximately eightfold increase in the number of prompts sent compared to traditional EMA studies (Intille et al., 2016; Ponnada et al., 2017)

Temporal Dynamics of Within-Person Association Between Physical Activity and Affect

The results from this thesis allude to the complex temporal dynamics of the within-person relationship between physical activity and affect. These findings have some potentially important implications regarding the timing of the examination of this relationship. Specifically, results showed that the within-person association between physical activity and affect may be short-lived and may not be captured when examining the association over a longer period. For example, results from Chapters 3 and 4 showed that being more active in a 15-minute window before an EMA prompt was associated with experiencing more energetic arousal and tense arousal, whereas results from Chapter 6 showed that participants did not report feeling more energetic or tense on days during which they were more active than they usually were. This adds to previous research which showed that there was an improvement in positive affect immediately after an increase in physical activity in daily life and that this improvement in positive affect lasted for approximately 180 minutes in a sample of women (Wichers et al., 2012). Similarly, results from a study of young adults showed that the within-person association between physical activity and energetic arousal and tense arousal was strongest when physical activity was measured in the 15-30 minutes before an EMA prompt and the association became weaker when physical activity was measured over longer periods of time (Reichert et al., 2017). The results from the current thesis and these previous studies indicate that the effect of physical activity on affect may be diluted over time.

These results support the Dual-Mode Model, which suggests that the affective response *during* and *following* participation in MVPA is likely different and affect may rebound after completing a physical activity (Ekkekakis, 2003; Ekkekakis et al., 2011). This is also consistent with the homeostatically protected mood hypothesis, which proposes that individuals have a steady-state affective set-point, which is relatively positive, between 70-80% of an affective scale (Cummins, 2010). Although affect can rise above or fall below this set-point, over time a homeostatic process will return affect to this set-point (Cummins, 2010). Therefore, as shown by the results of this thesis, although there may be an acute effect of participation in physical activity on affect, there may be a return to some affective homeostasis over the course of a day. This has some important implications for future research. Careful consideration must be taken when deciding on the duration of time over which physical activity is measured in EMA studies. If researchers wish to capture the within-person association between physical activity and affect during physical activity, they should use shorter windows, such as 15 minutes before an EMA prompt (Dunton, Liao, Intille, Spruijt-Metz, et al., 2011). Alternatively, researchers could use an experience sampling methodology, whereby participants indicate when they are initiating a physical activity and measuring affect during the activity in daily life (e.g., Williams et al., 2016). Alternatively, researchers could use a phones built in GPS (e.g., Reichert et al., 2017), or link phones to accelerometers (e.g., Ebner-Priemer et al., 2013) to prompt participants when they engage in physically active behaviours.

Theoretical Implications

The results from this thesis have some important theoretical implications for the examination of the within-person relationship between physical activity and affect. The most widely used model, the Dual-Mode Model, recognises how physical activity characteristics (i.e., intensity) and individual factors (i.e., cognitive factors and interoceptive cues) may influence the within-person association between physical activity and affect (Ekkekakis, 2003; Ekkekakis et al., 2011). The results from this thesis suggest that, in addition to physical activity characteristics and individual factors, it may be important to consider multiple other levels of influence and recognise that physical activities are embedded within broader social contexts and physical environments. Figure 7.2 displays a proposed model for examining the within-person association between physical activity and affect in daily life.

The model, based on an extensive review of the literature and the results presented in this thesis, combines concepts from exercise, social, environmental, and cognitive psychology, and illustrates how multiple levels of influence may impact the within-person association between physical activity and affect. Furthermore, given the layered nature of the model, it recognises that multiple levels of influence may interact to determine the within-person association between physical activity and affect. For example, as discussed in Chapter 5, other people in an adolescent's social context during physical activities may support or hinder the fulfillment of the basic psychological needs of competence, autonomy, and relatedness, and therefore may influence the within-person association between physical activity and affect through cognitive factors. Additionally, in support of interactions across other levels of influence, some research suggests that the physical environment and social context may interact to determine the within-person association between physical activity and affect in young adults (Johansson et al., 2011).

Additionally, although not explored in this thesis, it is important to note that individual trait level characteristics may also moderate the within-person association between physical activity and affect. Some theories propose that genetic factors will moderate the within-person association between physical activity and affect (Bryan et al., 2007; de Geus & de Moor, 2008; Lee et al., 2021). Other factors that may moderate the affective response during physical activity include an individual's physical and mental health status. For example, EMA studies have demonstrated that the within-person association between physical activity and affect may be moderated by an adolescent's body mass index (Smith, Mason, et al., 2020), and presence of mental or neurodevelopmental disorders (Gawrilow et al., 2013; Kolar et al., 2020). Although it may not be possible to manipulate individual's personal characteristics, especially in the short term, it is still important to consider how they influence people's affective experiences during physical activity. Certain physical activity characteristics, and psychological and contextual factors that may generally be associated with a positive affective experience, may have a different association in certain subgroups. For example, young women with social physique anxiety may experience more favourable affect while being active alone than with other people (Focht & Hausenblas, 2006). Therefore, more research on specific subgroups of adolescents is warranted.

The proposed model, integrating the concept of hedonic motivation (Williams, 2018), and recognising the importance of lived experiences on the formation of motivation (Brand & Ekkekakis, 2018; Conroy & Berry, 2017; Ekkekakis & Brand, 2019; Rhodes & Kates, 2015; Stevens et al., 2020; Sudeck et al., 2016; Williams & Evans, 2014), recognises that affect experienced during physical activity will feedback into the framework as hedonic motivation to participate in physical activities. However, the framework proposes not only will affective experiences shape hedonic motivation towards physical activity in general; it is posited that affective experiences will shape hedonic motivations towards specific physical activity characteristics and the contexts in which they occur. There is some empirical evidence supporting this proposition. For example, previous research shows that people will form an intention to choose or avoid a walking route based on their previous affective experience on that route (Bornioli et al., 2019; Johansson et al., 2016). Additionally, Boyle et al. (2020) found that the effect of the social context on future participation in physical activity was mediated by the affective response to walking with someone. Therefore, positive affective experiences while walking with someone else are likely associated with more hedonic motivation to walk with others in the future, whereas a negative affective experience while walking with others are likely associated with less hedonic motivation to be active with others in the future.

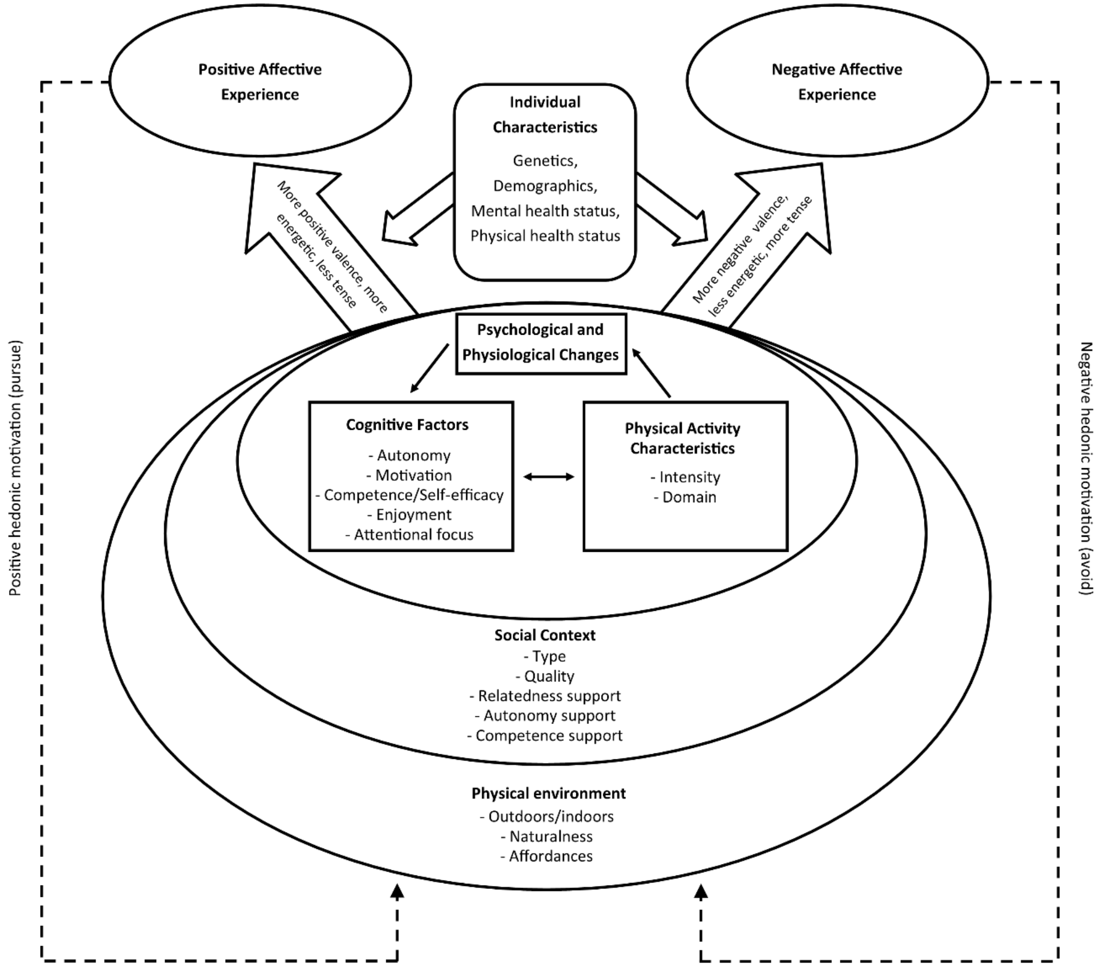

Figure 7.2 Proposed multi-level theoretical model of factors influencing the within-person association between physical activity and affect

Practical Implications

The results from this thesis can help inform the development of future interventions that aim to increase physical activity in adolescents. As discussed in the introduction, affect experienced during physical activity is implicated in the maintenance of physical activity behaviours in adolescents through both cognitive and non-cognitive processes of motivation (Brand & Ekkekakis, 2018; Conroy & Berry, 2017; Stevens et al., 2020; Williams & Evans, 2014; Williams et al., 2019).

Results from Chapter 4 showed adolescents may experience more favourable affect during physical activities when they are completed outdoors and with other people. Therefore, delivering physical activity interventions outdoors and in groups may potentially be more effective at increasing adolescent’s long-term physical activity behaviours. The potential of physical activities delivered outdoors and with others to promote more favourable affect and consequently greater physical activity intentions and behaviours has been demonstrated in adults (Boyle et al., 2020; Focht, 2009; Krinski et al., 2017; Lacharité-Lemieux et al., 2015).

However, as highlighted in Chapter 5, adolescents may have different perceptions about physical environments and social contexts that will promote more favourable affect during physical activity. For example, some participants described how they found being physically active alone more pleasurable and calming, whereas other preferred to be active with others. Therefore, it may be important that interventions can be individualised and allow adolescents to seek out the physical environments and social contexts in which they personally experience more favourable affect while active.

Future Directions

Evidence of Causality

Although this thesis has simultaneously examined the within-person and between-person association between physical activity and components of subjective wellbeing, adding to the confidence in the conclusions drawn, the non-experimental nature of the study means that conclusions cannot be drawn about causality. Although there is an abundance of cross-over and controlled trials examining the within-person association between physical activity and affect in laboratory studies, there is very little research using a combination of EMA and experimental study designs to study factors that influence the within-person association between physical activity and affect in daily life.

One example of a study that used both an EMA and experimental study design examined whether participants randomised to receive recommendations to participate in self-paced physical activities reported more positive valence during physical activity in daily life than participants who received recommendations to participate in physical activities at a prescribed intensity (Williams et al., 2016). Participants randomised to receive self-paced recommendations for physical activity reported more positive valence during exercise than participants randomised to receive recommendations to be physically active at a prescribed intensity, indicating that autonomy likely moderated the within-person relationship between MVPA and affect. However, the study was not adequately powered to determine if this effect was significant. Similarly, Baldwin et al. (2016) examined whether participants randomised to be physically active at an intensity that felt pleasant in daily life reported more positive remembered valence during physical activities than participants randomised to be physically active at a prescribed intensity using daily diaries. They found that, among participants with low cardiorespiratory fitness, participants randomised to be active at an intensity that felt pleasant reported more positive remembered valence than participants randomised to be active at a prescribed intensity. However, again, this study was not adequately powered to determine if the effect was significant.

Although these studies provide some initial evidence that more autonomy over physical activities may cause a more positive within-person association between physical activity and affect in daily life, this research is very preliminary. Additionally, there are many more cognitive and contextual mechanisms that ought to be explored. Therefore, future research should employ an experimental design which target cognitive and contextual factors coupled with EMA to see how they influence the within-person association between physical activity and affect in daily life.

In addition to randomised controlled trials, such as those described above, researchers could use a micro-randomised control trial design (Golbus et al., 2021; Klasnja et al., 2015) to determine the effect of a just-in-time adaptive intervention (JITAI) (Intille, 2004; Spruijt-Metz & Nilsen, 2014) on the within-person relationship between physical activity and affect. JITAIs are dynamic interventions delivered using mobile devices where multiple different micro-interventions are delivered to an individual over time (generally over multiple days/weeks) (Nahum-Shani et al., 2015; Nahum-Shani et al., 2018). The micro-randomised control trial design involves randomising the intervention content a participant will receive each time they receive a micro-intervention (Golbus et al., 2021; Klasnja et al., 2015). Analysis of micro-randomised controlled trials of JITAIs allows researchers to determine if different intervention content effects proximal outcomes differently (Golbus et al., 2021; Klasnja et al., 2015). Although a relatively new concept, the number of JITAIs targeting physical activity and sedentary behaviours is rapidly growing (Hardeman et al., 2019). Common behaviour change techniques used in these JITAIs include prompts/cues to be active, goal setting, action planning, and feedback on behaviours (Hardeman et al., 2019). Therefore, randomizing participants to receive slightly different prompts (e.g., prompting participants to be active outdoors vs. indoors) and goals (e.g., to be active for 60 minutes at a prescribed intensity vs. to be active for 60 minutes doing something they enjoy) and continuously monitoring affect using EMA could be used to determine how cognitive and contextual factors are causally related to the within-person association between physical activity and affect in daily life.

Mechanisms Explaining the Domain Specific Association Between Physical Activity and Wellbeing

With regards to the between-person association between MVPA and wellbeing, more research is needed to understand the mechanisms that explain why leisure-time physical activity, and not other forms of MVPA, are related to subjective wellbeing. There has been an attempt to synthesise the evidence regarding mechanisms that explain the mental health benefits of participation in physical activity (Lubans et al., 2016). In this review it was found that there was limited research exploring mechanisms that explain the relationship between physical activity and mental health. Nevertheless, researchers concluded that the strongest evidence was for physical self-concept being a mediator of the association between physical activity and mental health. Given that leisure-time physical activity may be more likely to promote positive self-concept in youth than other domains of MVPA such as active travel or household physical activity (Babic et al., 2014), this is a plausible mechanism that deserves further attention to determine whether it explains the domain specific association between MVPA and subjective wellbeing.

Outside of self-concept there is a paucity in research examining other potential behavioural, psychosocial, and neurobiological mechanisms that may explain the association between MVPA and mental health outcomes (Kandola et al., 2019; Lubans et al., 2016), let alone whether mechanisms operate in the same way across different domains of physical activity (White et al., 2017). Understanding the mechanisms that explain why leisure-time physical activity is more strongly associated with subjective wellbeing will allow for researchers to tailor their physical activity interventions to promote the greatest improvement in subjective wellbeing in adolescents.

Strengths and Limitations

Specific strengths and limitations for each component of this thesis are discussed in previous chapters. This section discusses the overall strengths and limitations of this thesis.

A major strength of this thesis is using a mixed methods design to examine factors that influence the within-person association between physical activity and affect. Using a sequential design means that the qualitative results can provide a more detailed understanding of initial quantitative results. Although the results from the EMA study identified factors that influence the within-person association between MVPA, the results from the qualitative component of this thesis provides further insights into the specific reasons why relationships were, or were not, identified.

Another strength of this thesis is the use of accelerometery and EMA to collect data from participants. A limitation of studying domain specific physical activities and physical activity contexts is that they necessarily require participant self-report. Therefore, data can be distorted by recall and social desirability biases (Sallis & Saelens, 2000). However, by asking participants to report on their momentary behaviours and context, results are less likely to be influenced by recall bias (Dunton, 2017). Additionally, using accelerometers to objectively measure levels of MVPA adds further confidence to the accuracy of the measurement of physical activities in this study. In addition to collecting data about physical activity behaviours and contexts, using EMA also has advantages for measuring affect. When asked to report on their affective states over an extended period time, people's responses will likely be influenced by memory heuristics bias and differ considerably from feelings that were actually experienced (Robinson & Clore, 2002; Trull & Ebner-Priemer, 2013). Therefore, measuring momentary affect using EMA means that participants reported on affect as it was experienced, rather than affect as it was remembered. This provides a more accurate picture of what an adolescent's affective experiences actually "looks and feels like" (Russell & Gajos, 2020). This will likely provide a more accurate depiction of adolescents affect compared to cross-sectional studies which are based on a single report of recalled affect. Therefore, although a major advantage of using EMA is that it allows for the examination of within-person processes, using EMA also has considerable advantages when examining the between-person association between physical activity and affect.

Despite the strengths of this thesis, there are some limitations that exist. First, participants were recruited from advertisements on social media and word of mouth, meaning that participants self-referred to the study. Therefore, it may be possible that there was a self-selection bias, and the study population may not be representative of the wider adolescent population. For example, it appears that adolescents who agreed to participate were highly active and from affluent areas. Caution must be taken when generalizing the results of this thesis to the broader population.

Second, despite this thesis disaggregating the within-person and between-person effects of physical activity, adding to the confidence in the conclusions drawn, the non-experimental nature of the study means that conclusions cannot be drawn about causality. Additionally, the analyses used to examine the association between physical activity, affect and satisfaction with life was essentially cross-sectional, and therefore cannot determine the directionality of associations. Future studies should use cross-lagged designs to further understand the direction of the association between physical activity, affect and satisfaction with life.

Finally, compliance rates were lower than the average found in a meta-analysis of EMA studies involving children and adolescents (Wen et al., 2017). However, the compliance rate of the current study fell within the 95% confidence interval of the average compliance rates in the meta-analysis, indicating that the compliance rate in the present study was not significantly different from other studies. Additionally, compliance differed between sexes, ages, time of day, and day of the week, indicating that data was not missing completely at random. However, consistent with the current study, other studies have shown that compliance rates are lower in males, on weekends and in the mornings (Rintala et al., 2019; Sokolovsky et al., 2013). Lower compliance in the morning could be a result of the first prompt being sent as early as 7:45 am which may have been received while participants were asleep, especially on weekends, or during a busy time preparing for school on weekdays, presumably increasing the likelihood that participants would miss the prompt. Similarly, participants may have been busy with other commitments or activities on weekends (e.g., organized sports), explaining why compliance rates were lower on weekends.

Conclusion

Overall, the results from this thesis show that multiple contextual factors can influence the association between physical activity and affect. Findings suggest that there may be some added and synergistic benefits to being physically active outdoors and with someone else on affect. Additionally, adolescents may feel a sense of excitement (i.e., more energetic and tense arousal) when participating in recreational physical activities, but not other domains of physical activity in daily life. These findings highlight why it is important to consider the context in which physical activities occur when examining the within-person association between MVPA and affect. Recreational physical activities also appear to have the most favourable between-person association with affect and satisfaction with life. These results add to the growing recognition of the domain specific association between physical activity and mental health.

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Appendix A – Published Review Articles

INTERNATIONAL REVIEW OF SPORT AND EXERCISE PSYCHOLOGY
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REVIEW

Variance in the valenced response during moderate-to-vigorous physical activity: a review of cognitive and contextual mechanisms

Matthew Bourke[a], Toni A. Hilland[b] and Melinda Craike[a,c]

[a]Institute for Health and Sport (IHES), Victoria University, Melbourne, Australia; [b]School of Education, College of Design and Social Context, RMIT, Bundoora, Australia; [c]Australian Health Policy Collaboration, Victoria University, Melbourne, Australia

ABSTRACT
It is hypothesised that various factors may explain variation in the valenced (pleasure-displeasure) response to moderate-to-vigorous physical activity (MVPA), however the empirical evidence for these factors has not been reviewed. This narrative review summarises empirical evidence relating to cognitive and contextual mechanisms that may explain inter- and intra-individual variation in the valenced response to MVPA. The mechanisms included in this review include (i) cognitive factors: motivation, autonomy, competence, task self-efficacy, attentional focus and relatedness, (ii) the social context, and (iii) the physical environment. The electronic databases Medline, PsychINFO and SPORTDiscus were searched to identify relevant articles. Different factors may explain inter- and intra-individual variations in the valenced response to MVPA. Factors that consistently explain inter-individual variations in the valenced response to MVPA include self-determined motivation, physical activity competence and task self-efficacy. Considering intra-individual variations, people may have a more pleasurable experience during MVPA when they have more dissociative thoughts, and when they participate in the MVPA outdoors. Implications of these findings are discussed and future research directions are suggested.

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Introduction

The preventative health benefits of regular participation in moderate-to-vigorous physical activity (MVPA) on several non-communicable diseases is well documented (Warburton & Bredin, 2017). However, global estimates based on self-reported data indicate that 27.5% of the adult population and 81% of adolescents worldwide are insufficiently active, based on the World Health Organisation's physical activity guidelines (Guthold et al., 2018, 2020; World Health Organization, 2010). Rates of physical inactivity are even higher in high-income Western countries, where it is estimated that 42.3% of adults do not achieve recommended levels of MVPA based on self-reported data (Guthold et al., 2018). Consequently, physical inactivity is projected to cause between 6% and 10% of major non-

CONTACT Matthew Bourke matthew.bourke6@live.vu.edu.au

communicable diseases worldwide, similar to the health impact of smoking and obesity, and is the fourth leading cause of mortality (Lee et al., 2012; World Health Organization, 2009). Promoting MVPA has therefore been recognised by the World Health Organisation as a public health priority in efforts to prevent and treat non-communicable diseases worldwide (World Health Organization, 2018).

Theories based on cognitive and social constructs such as the Social Cognitive Theory (Bandura, 1986) and the Theory of Planned Behaviour (Ajzen, 1991), have been commonly used to explain participation in MVPA (Rhodes & Nigg, 2011). However, these theories predict only 24–31% of the variance in physical activity behaviours in adults (McEachan et al., 2011; Young et al., 2014) and 33% of the variance of physical activity behaviours in youth (Plotnikoff et al., 2013). Further, physical activity interventions based on these theories only lead to modest, short term increases in MVPA (Conn et al., 2011; Gourlan et al., 2016; Rhodes et al., 2017). Given the limited predictive capabilities of these theories, questions have been raised about their utility, validity, and hypothesised mechanisms (Beauchamp et al., 2019; Sniehotta et al., 2014; Williams, 2010). These models, as well as several other models falling within the social-cognitive archetype including the Transtheoretical Model (Prochaska & Velicer, 1997), the Health Belief Model (Rosenstock et al., 1988), and Socio-Ecological Models (Sallis et al., 2006), focus on the cognitive influences at the expense of affective influences on behaviour (Conner et al., 2013). Additionally, these models explicate the effect of explicit attitudes and motivations on behaviour but fail to consider the possible influence of implicit attitudes, such as implicit affective attitudes shaped through lived physical activity experiences (Ekkekakis, 2017).

Given these shortcomings of social cognitive models, the field of exercise psychology is undergoing a theoretical transition to examine the influence of other factors related to MVPA. The affective experience during MVPA is one such factor that has garnered increasing research attention (Ekkekakis et al., 2013). One dimension of the affective experience during MVPA is the valenced response; that is the pleasure an individual experiences when physically active (Russell, 1980). Understanding the valenced response during MVPA is important because it is a significant predictor of future MVPA intentions and behaviours (Rhodes & Kates, 2015). This is consistent with hedonic principals which postulate that humans organise behaviours to enhance positive feelings and reduce distress (Young, 1952). Whether an individual experiences feelings of pleasure during MVPA may shape affective judgements (Rhodes & Kates, 2015), which may have a stronger and more temporally salient association with MVPA behaviours than instrumental judgements (Rhodes & de Bruijn, 2013a; Rhodes & Yao, 2015; Rhodes et al., 2009). Additionally, dual-process models recognise the importance of past affective experiences in shaping automatic affective valuations of MVPA, which may determine impulses to approach or avoid MVPA behaviours (Brand & Ekkekakis, 2018; Conroy & Berry, 2017; Williams & Evans, 2014). As such, individuals are more likely to approach physical activities that are implicitly associated with feelings of pleasure and avoid those that are not (Chevance et al., 2019).

Seminal work on the valenced response to physical activity led to the development of the dual-mode model which posits there is a dose–response pattern between physical activity intensity and affective valence (Ekkekakis, 2003). The model proposes that the valenced response to physical activity is the product of the interplay between two general factors: cognitive processes and interoceptive cues from a variety of receptors stimulated by physiological changes during physical activity. It suggests that physical activity below an individual's ventilatory or lactate threshold presents no threat to an individual's physiological homeostasis and is therefore generally a pleasant experience. Appraisals of activities above the ventilatory or lactate threshold will be based on negative interoceptive cues resulting from physical activity induced physiological changes, such as perceived muscle soreness or difficulty breathing and will lead to a homogenous negative valenced response. However, when physical activities are completed at moderate-to-vigorous intensities corresponding with an individual's ventilatory or lactate threshold, heterogeneity in valenced response is observed (Ekkekakis, 2003; Ekkekakis et al., 2005b).

Ekkekakis et al. (2005b) suggest that during MVPA, completed near or at an intensity corresponding to the ventilatory or lactate threshold, cognitive factors are likely to have the greatest influence on inter-individual variations in pleasantness during MVPA (i.e. the heterogeneity in the valenced response to MVPA between individuals). Due to the scarcity of experimental studies that went beyond simply describing the affective response to MVPA when the dual-mode model was proposed, it was only possible to speculate about the influence of cognitive factors on the valenced response to MVPA (Ekkekakis, 2003). However, as research into the affective response to MVPA has increased, so has our understanding of possible mechanisms that may explain inter-individual variation in this relationship (Ekkekakis et al., 2013). That is, differences in the affective response between-individuals (i.e. why does one individual's affective response differ from another individual?). Additionally, considering that there is no archetypical physical activity behaviour or context, it is possible that several factors may explain intra-individual variations in the valenced response to MVPA (Backhouse et al., 2007). That is, differences in the affective response within-individuals (i.e. why is an individual's affective response different on one occasion compared to another?). Therefore, it is important to also understand factors that may explain differences in affective response to MVPA within individuals.

There are several cognitive and contextual factors that are theorised to effect psychological outcomes during physical activity (Araújo et al., 2019; Ekkekakis et al., 2013; Rose & Parfitt, 2007, 2010; Shanahan et al., 2016). Factors from the Self Determination Theory (SDT), and its related sub theories, may be important to understanding the psychological outcomes from participation in physical activity (Ryan et al., 2009; Teixeira et al., 2012). For example, the Basic Psychological Needs Theory, a sub theory of the SDT, suggests that the satisfaction of the needs of competence, autonomy and relatedness predict psychological wellbeing (Deci & Ryan, 2008). Therefore, the satisfaction of these needs will likely promote greater sense of wellbeing during physical activities (Wilson & Rodgers, 2007). Having autonomy over physical activities may promote a sense of wellbeing by allowing participants to self-regulate behaviours, allowing them to choose preferred physical activity modes and intensities which may lead to more positive affective outcomes (Ekkekakis, 2009). Perceived competence during physical activity may foster feelings of ability, accomplishment and satisfaction which may be associated with perceptions of pleasure during MVPA (Rose & Parfitt, 2007, 2010). Additionally, feelings of relatedness during physical activity may be accompanied by feelings of connectedness, inclusion, and being cared for (Ryan et al., 2009).

The SDT suggests that whether or not the basic psychological needs are satisfied will determine which behaviours are intrinsically or extrinsically motivated (Ryan & Deci, 2000). Greater perceived autonomy, competence and relatedness will foster more intrinsic motivations towards behaviours. Within the context of physical activities, it is suggested that intrinsic motivations are associated with positive psychological outcomes, whereas extrinsic motivations are not associated with positive outcomes, even when attained (Ryan et al., 2009).

The Cognitive Evaluation Theory, another sub theory of the SDT, outlines the social psychology of intrinsic motivation, and explains how the social context can impact on intrinsic motivation (Ryan et al., 2009). Social context may support intrinsic motivation for physical activity by providing autonomy support, competence support (i.e. structure), and relatedness support (i.e. involvement) (Hagger & Chatzisarantis, 2007; Ryan et al., 2009; Wilson et al., 2008). For example, other people may promote competence by providing positive feedback throughout an activity or promoting a mastery environment, others may thwart autonomy by being controlling or coercive, and being included by others during an activity may promote relatedness (Ryan et al., 2009). In addition to the hypotheses of the Cognitive Evaluation Theory, stress-buffering models theorise that social interactions may influence psychological outcomes through reducing the impact of stress (Cohen et al., 2000). Social interactions may provide information about ways to cope with stress and increase an individual's perceptions of self-esteem and feelings of personal control (Cohen, 1988; Cohen et al., 2000).

Another cognitive factor that may influence the valenced response during physical activity is attentional focus. There are two key attentional focus styles, association and dissociation. Association is characterised by focusing on and monitoring bodily sensations during physical activity, whereas dissociation is characterised by focusing cognitions on external stimuli (Masters & Ogles, 1998). Tenebaum (2001) suggests that as physical activity intensity increases, people begin to shift towards a more associative attentional focus. However, Tenebaum (2001) also suggest that being able to maintain dissociative attentional focus during more intense physical activities may improve an individual's ability to tolerate MVPA and therefore have more positive valanced response.

The physical context may also influence and individual's affective experience when physically active. Evolutionists argue that humans have a naturalistic tendency to pay attention to, associate with, and respond positively to natural environments (Kellert, 1993). It is suggested people may have a number of different positive responses to natural environments including stress reduction, attention restoration, like/approach impulses, and higher order cognitive functioning which may all contribute to more pleasurable experiences (Ulrich, 1993). Additionally, the ecological dynamics approach suggests natural environments produce a positive affective response because they afford a greater diversity of behaviours that can promote wellbeing (Araújo et al., 2019; Brymer et al., 2014; Yeh et al., 2016).

To date, there are no published reviews about the effect of possible mechanisms explaining inter- and intra-individual variance in the valenced response to MVPA. To address this gap, the current narrative review explores the potential effect of a range of mechanisms that have the potential to influence the valenced response to MVPA. These mechanisms include (i) cognitive factors: motivation, autonomy, competence, task self-efficacy, attentional focus and relatedness, (ii) the social context, and (iii) the physical environment. Although other mechanisms have been theorised to influence the valenced response to physical activity including physiological and genetic factors (Bryan et al., 2007; de Geus & de Moor, 2008), as well as other dispositional factors including preference, tolerance (Ekkekakis et al., 2005a) and personality (Schneider & Graham, 2009), these factors are likely to remain constant across time, activities and contexts. The mechanisms included in this review are more malleable and may be manipulated through intervention to promote more positive valenced outcomes during physical activity.

Methods

To achieve the aims of the study, a narrative review was conducted. Given the wide scope of this review, conducting a systematic review was neither feasible nor appropriate (Collins & Fauser, 2005; Ferrari, 2015). This review followed processes consistent with recommendations for conducting and reporting narrative reviews (Green et al., 2006).

Search strategy and inclusion criteria

To identify studies that have examined the association between theorised mechanisms with the valenced response to MVPA, the electronic databases Medline, PsychINFO and SPORTDiscus were searched from any time up to January 2020 with a combination of keywords for the outcome ('affective response' OR valence* OR hedoni* OR 'feeling scale' OR fs OR 'psychological state*' OR pleasant* OR pleasur*), condition ('physical* activit*' OR exercis* OR mvpa), and theorised mechanisms (motivation OR intrinsic OR extrinsic OR autonom* OR choice OR 'self-determined' OR competence OR 'self-efficacy' OR relatedness OR alone OR together OR others OR social OR group OR attention* OR dissociati* OR associative OR green OR outdoors OR indoors OR natur* OR environment). Article titles, abstracts and full texts were screened by a single author to determine relevance. Additionally, the reference list of all included articles were manually searched by a single author to identify any further relevant articles. Articles were included if they: (a) examined the acute association between MVPA and affective valence during or immediately following participation in MVPA, (b) an objective measure of physical activity intensity was used and is consistent with published definitions of MVPA (Norton et al., 2010), or the activity is sufficiently described that a determination can be made that its intensity is consistent with MVPA (i.e. ≥3 METs) using the Compendium of Physical Activities (Ainsworth et al., 2011); (c) examined the effect of one or more of the hypothesised mechanisms, and (d) were written in English and peer reviewed. Studies were excluded if they: (a) examined the effect of MVPA on distinct moods or emotion; (b) examined the relationship between light physical activity and valence or the activity was not sufficiently described that a determination about it's likely intensity could be made; and (c) were grey literature. There was no age limit on the studies included in this review. A flow chart of the review process can be seen in Figure 1.

Data extraction and presentation

For each of the included studies, data was extracted for sample characteristics, study design, measures of MVPA and valence, the mechanism tested and how it was measured, the level of analysis and the key findings. Key findings are presented in terms of statistical significance and strength of association where standardised effect sizes were reported in the original article. A descriptive overview of studies included in the review can be seen in

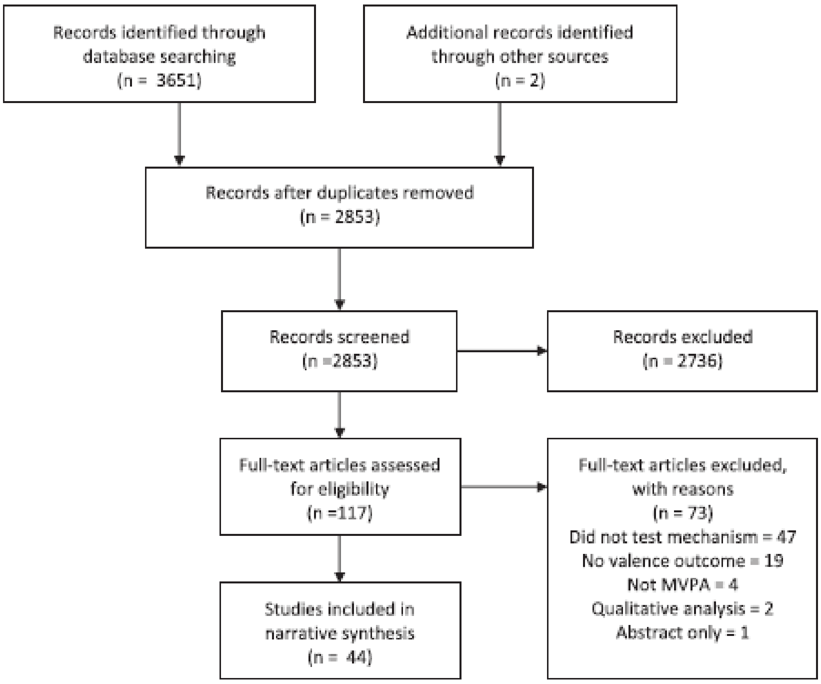

Figure 1. Study flow diagram.

Table 1. Results of individual studies were organised based on the mechanism tested and level of analysis, and a description of findings for each mechanism is provided below.

Results

Overview of studies

Overall, 44 studies were identified that met the inclusion criteria (See Table 1). Most studies were experimental ($n = 38$) and involved adult participants ($n = 42$). Additionally, 13 studies only recruited females, 11 recruited active participants or members of an exercise group, and seven recruited inactive participants. The most common physical activities reported include walking/running ($n = 23$), stationary cycling ($n = 12$) and group exercise classes ($n = 6$). Almost all studies ($n = 39$) used the Feeling Scale to measure valence.

Self-determined motivation

A number of studies support the proposition that motivation is a mechanism that explains inter-individual variance in the valenced response to MVPA. In their study involving young and middle aged women, Jones et al. (2017), found that participant's motivation to be physically active was significantly correlated to affective valence after completing

Table 1. Overview of included studies.

Reference	Country	Sample characteristics	Study design	Physical activity mode, length and intensity	Valence outcome	Mechanisms tested	Description of mechanism assessment	Level of analysis	Key findings
Barnett (2013)	Australia	25 younger and 25 older women Mean age = 37.8 ± 18.1 100% female	Experimental	Cycling ergometer 20-minutes 60% VO2max	FS during physical activity (min 10)	Task self-efficacy	Confidence to cycle at 60% VO2max without stopping for 5, 10, 15, and 20 min	Inter-individual	• Pre-task self-efficacy not related to FS during physical activity ($r = 0.21$, $p > .05$) • Post-task self-efficacy positively related to FS during physical activity ($r = .046$, $p < .05$)
Bigliassi et al. (2019a)	United Kingdom	24 adults Mean age = 28.3 ± 5.5 Gender NR	Experimental	Recumbent cycling ergometer 10-minutes Self-paced	FS during physical activity (mins 0.5, 2.5, 5, 7.5 & 9)	Attentional focus (manipulated using audio-visual stimuli)	Tammen's Single-Item Attention Scale	Intra-individual	• FS more positive during sensory stimulation (dissociative condition) than sensory deprivation at all time points ($p < .001$) and control at 2.5, 5, 7.5, and 9 mins ($p < .05$)
Bigliassi et al. (2019b)	United Kingdom	24 adults Mean age = 23.5 ± 4.3 46% female	Experimental	Walking (outdoors) 1 lap of 400 m running track Self-paced	FS immediately following physical activity	Attentional focus (manipulated using audio stimulus)	Tammen's Single-Item Attention Scale	Intra-individual	• FS more positive immediately following music condition (dissociative condition) than control condition ($p < .001$), and podcast condition ($p = .029$)
Bird et al. (2019)	United Kingdom	18 adults Mean age = 24.2 ± 4.2 50% female	Experimental	Cycling ergometer 10-minutes VT	FS during physical activity (mins 3, 6 & 9)	Attentional focus (manipulated using audio-visual stimuli)	Tammen's Single-Item Attention Scale	Intra-individual	• No significant difference in FS between conditions ($p = .654$)
Cabrita et al. (2017)	Netherlands	10 older adults Mean age = 68.7 ± 5.5 60% female	Ambulatory assessment	Device measured physical activity in daily life 10-minute windows centred	Perceived pleasure	Social context	Alone vs. with someone else	Intra-individual	• Social context did not moderate the relationship between physical activity and pleasure ($p > .10$)

(*Continued*)

Table 1. Continued.

Reference	Country	Sample characteristics	Study design	Physical activity mode, length and intensity	Valence outcome	Mechanisms tested	Description of mechanism assessment	Level of analysis	Key findings
				around each prompt					
Casado et al. (2019)	Spain	16 elite middle-distance runners Mean age = 24 ± 4 19% female	Experimental	High-intensity running intervals (outdoors) 4 × 500 metres Self-paced	FS immediately following each interval	Social context	Completing physical activity alone vs. in a group	Intra-individual	• FS more positive immediately following intervals completed in a group than intervals completed alone ($p = .001$)
Cox et al. (2018)	United States	23 undergraduate university students Mean age = 19.3 ± 1.1 83% female	Experimental	Walking/running (treadmill) 10-minutes 65% HRR	FS during physical activity (mins 4 & 8)	Attentional focus (manipulated using mindfulness task)	Tammen's Single-Item Attention Scale	Inter- and intra-individual	• FS more positive during mindfulness condition (associative condition) than the control condition ($p = .02$) • Attentional focus was not correlated with FS during physical activity in the control condition ($r = 0.11$, $p > .05$) or experimental condition ($r = -0.16$, $p > .05$)
Cox et al. (2019)	United States	31 inactive women Mean age = 28.6 ± 9.9 100% female	Experimental	Walking/running (treadmill) 15-minutes Self-paced	FS during physical activity (mins 7 & 12)	Attentional focus (manipulated using mindfulness task)	Tammen's Single-Item Attention Scale	Intra-individual	• No difference in FS during test between conditions ($p > .05$)
da Silva et al. (2017)	Brazil	37 sedentary adults Mean age = 25.1 ± 4.6 76% female	Experimental	Cycle ergometer Incremental exercise test to exhaustion	FS after the completion of each stage	Attentional focus	Tammen's Single-Item Attention Scale	Inter-individual	• More associative thoughts were correlated with more negative FS during physical activity at participant's VT ($r = -0.32$, $p < .05$)
Dasilva et al. (2011)	Brazil	34 adults Mean age = 23.4 ± 3.0 50% female	Experimental	Walking (treadmill and athletics track) 20-minutes Self-paced	FS during physical activity (mins 5, 10, 15 & 20)	Physical environment	Treadmill vs. athletics track	Intra-individual	• FS was more positive in the outdoor condition than the indoor condition ($p < .01$)
De Brito Farias et al. (2018)	Brazil	15 older adults Mean age = 65.4	Experimental	Walking (gym, athletics track,		Physical environment	Gym vs. athletics track vs. beach	Intra-individual	• No difference in FS during physical activity

		±5.1 73% female		beach) 20-minutes Self-paced	FS during physical activity (mins 5, 10, 15 & 20)				completed indoors, athletics track, or at the beach ($p = 0.39$)
Ekkekakis et al. (2010)	United States	9 normal weight women, 8 women with overweight, and 7 women with obesity Mean age = 42.4 ±6.3 100% female	Experimental	Walking/running (treadmill) Incremental exercise task to maximal effort	FS during physical activity (each minute)	Task self-efficacy	Participants' beliefs in their ability to continue exercising for incremental 1-minute periods 'beyond the point at which exercise starts to become challenging'.	Inter-individual	• Self-efficacy was not correlated with the FS rating during the physical activity ($r = 0.24$–0.26, n.s)
Focht (2009)	United States	35 physically active young women Mean age = 22.1 ±1.7 100%female	Experimental	Walking (treadmill and urban outdoors) 10-minutes Self-paced	FS during physical activity (min 5)	Physical environment	Treadmill vs. urban outdoor	Intra-individual	• FS more positive in outdoor condition than the indoor condition ($d = 0.42$, $p < .001$)
Focht and Hausenblas (2006)	United States	30 inactive women with social physique anxiety Mean age = 20.2 ±1.7 100% female	Experimental	Cycling ergometer 20-mins Self-paced OR 70–80% HRmax	FS during physical activity (mins 5, 10, 15 & 20)	Social context	Public exercise centre vs. private room	Intra-individual	• Significant time x condition interaction on FS ($p < .001$) • FS increased from 0 to 15 ($d = 0.55$, $p < .01$) and 20 ($d = 0.86$, $p < .01$) mins when exercising alone and decreased from 0 to 5 ($d = -0.41$, $p < .01$) and 10 ($d = -0.40$, $p < .01$) mins, but increased from 0 to 20 mins ($d = 0.86$, $p < .01$) when exercising with others
Focht et al. (2007)	United States	18 young adults and 23 older adults Mean age = 42.3 ±20.9 52% female	Experimental	Cycling ergometer 20-minutes 65% VO2peak	FS during physical activity (min 10)	Task self-efficacy	Confidence to cycle at 65% VO2max without stopping for 5, 10, 15, and 20 min	Inter-individual	• Pre-task and post-task self-efficacy were not correlated to FS during physical activity
Frühauf et al. (2016)	Austria	14 mental health in-patients with mild to moderate depression	Experimental	• Walking (outdoor natural environment) • 60-minutes	FS during physical activity (mins 0, 15, 30, 45 & 60)	Physical environment	Indoor cycling vs. walking in natural environment	Intra-individual	• No statistically significant difference ($p = .103$) in changes in FS during physical activity

(Continued)

Table 1. Continued.

Reference	Country	Sample characteristics	Study design	Physical activity mode, length and intensity	Valence outcome	Mechanisms tested	Description of mechanism assessment	Level of analysis	Key findings
		Mean age = 32.7 ± 10.8 57% female		• Self-paced • Cycling ergometer 60-minutes Self-paced					completed outdoors (d = 1.44) and indoors (d = 0.64)
Gillman and Bryan (2016)	United States	28 regular exercising adults Mean age = 25.1 ± 5.7 54% female	Experimental	Walking/running (treadmill) 30-minutes VT	FS during physical activity (mins 5, 10, 15, 20, 25 & 30)	Motivation	Likert scale with anchors at serious (i.e. feeling that you are pursuing, or at least thinking about, some essential goal) and playful (i.e. feeling that you are in the moment, and doing what you are doing for its own sake)	Intra- and Inter-individual	• More playful motivations were correlated with more positive FS during physical activity (r = 0.403, p = .037) • Within-person changes in motivation were correlated with within-person changes in FS during physical activity (r = 0.614, p < .001)
Gillman and Bryan (2020)	United States	78 adults Mean age = 26.8 ± 6.6 74% female	Experimental	Walking/running (treadmill) 30-minutes VT	FS during physical activity (mins 0, 10, 20 & 30)	Attentional focus (manipulated using audio-visual and mindfulness task)	'I observed the exercise experience closely'; 'I paid close attention to the physical sensations caused by exercise'; 'I tried to stay focused on something other than my exercise experience'; and 'I concentrated on other things rather than the exercise experience'	Inter-individual	• Participants randomised to the distraction condition (dissociative condition) reported more positive FS during physical activity than participants randomised to associative focus condition (associative condition) (p < .05) • No difference in FS during physical activity between participants randomised to distraction condition (dissociative condition) and mindfulness group (p = .71)
Glen et al. (2017)	Australia	20 adults Mean age = 24.2 ± 5.9 80% female	Experimental	Recumbent cycling ergometer 15-minutes Self-paced	FS during physical activity (mins 3, 6, 9, 12 & 15)	Attentional focus (manipulated using visual-stimulus and exergaming)	Tammen's Single-Item Attention Scale	Intra-individual	• FS more positive during game mode (most dissociative) compared to audio-visual and control conditions (p < .01)

									• FS more positive during audio-visual (more dissociative) than control condition ($p < .01$)
Graupensperger et al. (2019)	United States	97 group fitness centre members Mean age = 42.4 ± 12.5 86% female	Ambulatory assessment	Group fitness classes Length NR Self-paced	FS during physical activity (measured retrospectively)	Social context	'Members of this class shared a collective goal.'; 'This exercise session felt like a team effort.'; 'The people in this class felt like a group (i.e. 'we') as opposed to simply a collection of individuals.'	Intra-individual	• Participants reported more positive FS during classes in which they perceived greater levels of entitativity ($p < .001$)
Hutchinson and Karageorghis (2013)	United States	34 physically active undergraduate university students Mean age = 19.2 ±4.9 35% female	Experimental	Walking/running (treadmill) 7-minutes 65% HRR and 85% HRR	FS during physical activity (mins 2, 4 & 6)	Attentional focus (manipulated using music)	Attentional Focusing Questionnaire	Inter- and intra-individual	• No difference in FS during physical activity between associators, dissociators and switchers ($p = .637$) • FS more positive during motivational music condition (dissociative condition) than oudeterous music and control conditions ($p < .001$)
Hutchinson et al. (2015)	United States	24 physically active adults Mean age = 21.3 ± 13.9 42% female	Experimental	Walking/running (treadmill) 15-minutes 10%>VT	FS during physical activity (mins 0, 5, 10 & 15)	Attentional focus (manipulated using audio-visual stimuli)	Tammen's Single-Item Attention Scale	Intra-individual	• FS more positive during music-video condition (most dissociative condition) than the music only and control condition ($p < .001$) • FS more positive during music only condition (more dissociative condition) than the control condition ($p < .001$)
Hutchinson et al. (2017)	United States	24 women with type 2 diabetes Mean age = 66.0 ± 8.5 100% female	Experimental	Group aerobic and resistance training exercise class 55-minutes 40–60% HRR	FS during physical activity (mins 20 & 40)	Attentional focus (manipulated using audio-visual stimuli)	Tammen's Single-Item Attention Scale	Intra-individual	• FS more positive during music-video condition (dissociative condition) than the control condition ($d = 0.56$, $p = .01$) • FS more positive during music only condition (dissociative condition)

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Table 1. Continued.

Reference	Country	Sample characteristics	Study design	Physical activity mode, length and intensity	Valence outcome	Mechanisms tested	Description of mechanism assessment	Level of analysis	Key findings
									than the control condition ($d = 0.57$, $p = .02$)
Jones and Ekkekakis (2019)	United Kingdom	21 inactive adults with overweight Mean age = 34.7 ± 9.6 76% female	Experimental	Recumbent cycling ergometer 15-minutes VT	FS during physical activity (mins 5, 10 & 15)	Attentional focus (manipulated using audio visual stimuli)	Tammen's Single-Item Attention Scale	Intra- and inter-individual	• FS more positive during high immersion condition (dissociative condition) than control condition during exercise ($d = 1.64$–2.57, $p < .001$) • FS more positive during high immersion condition (dissociative condition) than low immersion condition during exercise at 10 ($d = 0.55$, $p = .029$) and 15 mins ($d = 0.65$, $p = .014$)
Jones et al. (2014)	United Kingdom	38 moderately active adults Mean age = 21.1 ± 1.9 50% female	Experimental	Cycling ergometer 10-minutes 10%<VT or 5% >VT	FS during physical activity (mins 4 & 8)	Attentional focus (manipulated using audio-visual stimuli)	Tammen's Single-Item Attention Scale	Inter- and intra-individual	• FS more positive during music-and-video condition (dissociative condition) compared to video-only and control conditions ($p < .001$) • No difference in FS during physical activity between music-and-video condition (dissociative condition) and music-only condition • Dissociative thoughts was positively correlated with FS during physical activity completed at 5%>VT ($r = 0.40$–0.53, $p < .02$) but not during physical activity completed at 10%<VT ($r = 0.12$–0.29, $p > .05$)
Jones et al. (2017)	United Kingdom	434 female adults Mean age = 37.2 ± 13.8 100% female	Cross-sectional	Group exercise class Length NR Self-paced	Affect Grid after physical activity	Motivation and attentional focus	*Motivation* Exercise Motivation Scale *Attentional Focus* Attentional Focus Questionnaire	Inter-individual	• Intrinsic motivation ($r = 0.16$–0.19, $p < .01$) and integrated regulation ($r = 0.13$, $p < .01$) positively

									correlated with valence following physical activity • Amotivation ($r = -0.14$, $p < .01$) and external regulation ($r = -0.18$, $p < .01$) negatively correlated with valence following physical activity • Introjected ($r = -0.05$, $p > .05$) and identified regulation ($r = 0.09$, $p > .05$) not correlated with valence following physical activity • Valence immediately following physical activity was more positive in associators than dissociators ($p = .005$)
Kanning and Hansen (2017)	Germany	74 older adults Mean age = 60.1 ± 7.1 49% female	Ambulatory assessment	Device measured physical activity in daily life 10-minute window before each prompt	Valence subscale from the Multi-dimensional Mood Questionnaire	Autonomy, competence and relatedness	*Autonomy* Relative Autonomy Index *Competence* 'I felt capable and competent during my activities of the last 10 min.' *Relatedness* During the last 10 min, I was mainly … 'alone' or 'together with others.'	Intra-individual	• Autonomy augmented the relationship between physical activity and valence ($p = .01$) • Competence ($p = .59$) and relatedness ($p = .71$) did not moderate the relationship between physical activity and valence
Kanning et al. (2012)	Germany	44 university students Mean age = 26.2 ± 3.2 48% female	Ambulatory assessment	Device measured physical activity in daily life 10-minute window before each prompt	Valence subscale from the Multi-dimensional Mood Questionnaire	Autonomy	Relative Autonomy Index	Intra-individual	• Motivation did not moderate the relationship between physical activity and valence ($p = 0.82$)
Karageorghis and Jones (2014)	United Kingdom	22 undergraduate university students Mean age = 20.0 ± 1.6 50% Female	Experimental	Walking/running (treadmill) 6 × 2-minutes 40–90% HRR	FS during physical activity (15 s before the end of each bout)	Attentional focus (manipulated using music)	Tammen's Single-Item Attention Scale	Intra-individual	• FS more positive during music conditions (dissociative conditions) compared to the control condition ($p < .05$)
Karageorghis et al. (2013)	United Kingdom	26 female swimming club members Mean age = 20.0	Experimental	Swimming 200-metres	FS immediately after physical activity	Attentional focus (manipulated using music)	Attentional Focus Questionnaire	Intra-individual	• No difference is FS immediately following music conditions

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Table 1. Continued.

Reference	Country	Sample characteristics	Study design	Physical activity mode, length and intensity	Valence outcome	Mechanisms tested	Description of mechanism assessment	Level of analysis	Key findings
		±1.4 50% female		Self-paced (time-trial)					(dissociative conditions) compared to the control condition (p>.05)
Kinnafick and Thøgersen-Ntoumani (2014)	United Kingdom	30 physically inactive adults Mean age = 25.9 ±11.5 57% female	Experimental	Walking (urban and natural settings) 15-minutes Self-paced	FS during physical activity (min 7)	Physical environment	Urban outdoor vs. natural outdoor	Intra-individual	• FS during physical activity more positive when walking in natural environment compared to urban environment (p < .002)
Krinski et al. (2017)	Brazil	38 inactive women with obesity Mean age = 45.6 ±8.6 100% female	Experimental	Walking (treadmill and outdoor athletics track) 30-minutes Self-paced	FS during physical activity (mins 5, 10, 15, 20, 25 & 30)	Physical environment and attentional focus	*Physical environment* Treadmill vs outdoor athletics track *Attentional focus* Tammen's Single-item Attention Scale	Intra- and inter-individual	• FS more positive during physical activity outdoors (more dissociative thoughts) compared to physical activity indoors (p = .01) at 15 mins (d = 1.41), 20 mins (d = 1.00), 25 mins (d = 1.00), and 30 mins (d = 1.00) • Attentional focus was not correlated with FS during physical activity completed indoors (r = −0.16, p>.05) or outdoors (r = .06, p>.05)
Kwan et al. (2011)	United States	104 undergraduate university students Mean age = 18.2 58% female	Ambulatory assessment	Self-reported moderate and vigorous exercise in daily life	FS during physical activity (measured retrospectively)	Autonomy	Relative Autonomy Index	Inter-individual	• Autonomy orientation was positively associated with FS during physical activity (r = 0.34, p < .001)
Lacharité-Lemieux et al. (2015)	Canada	23 postmenopausal women Mean age = 60.7 ±4.8 100% female	Experimental	Group aerobic and resistance training exercise class (indoors and outdoors)	FS during physical activity (min 35)	Physical environment	Indoor gym vs. natural park	Inter-individual	• More positive changes in FS during physical activity in participants randomised to outdoor condition compared to participants randomised

				60-minutes 65–95% HRmax					to indoor condition (p = .029)
Niedermeier et al. (2017)	Austria	42 adult hiking enthusiasts Mean age = 32.0 (95%CI = 28.4–35.6) 48% female	Experimental	Walking/hiking (treadmill and natural environment) 180-minutes Self-paced (instructed to exercise at an intensity that was brisk without overspending)	FS during physical activity (mins 30, 105 & 140)	Physical environment	Treadmill vs. mountain hiking	Intra-individual	• More positive changes in the FS during physical activity in the outdoor condition compared to the indoor condition
Raedeke et al. (2009)	United States	99 female undergraduate university students with social physique anxiety Mean age = 19.0 ± 1.3 100% female	Experimental	Group exercise class 40-minutes Self-paced	FS immediately following physical activity	Task self-efficacy	Participants' confidence in their ability to complete various class components	Inter-individual	• Task self-efficacy was positively related to FS immediately following physical activity (p < .001)
Robbins et al. (2004)	United States	168 children and adolescents Mean age = 12.6 ± 2.3 49% female	Experimental	Walking/running (treadmill) 20-minutes 60% VO2peak	FS during physical activity (mins 4, 8, 12, 16 & 20)	Task self-efficacy	Participants' degree of confidence in their physical capabilities to walk at a fast pace without stopping for progressively longer periods of time	Inter-individual	• Pre-task (r = 0.20, p < .009) and post-task self-efficacy (r = .38, p < .001) were positively correlated with FS during physical activity
Rose and Parfitt (2012)	New Zealand	17 sedentary women and 15 physically active women Mean age = 45.1 ± 10.1 100% female	Experimental	Walking/running (treadmill) 30-minutes Self-paced and participant VT	FS during physical activity (mins 5, 10, 15, 20, 25 & 30)	Task self-efficacy, competence, and autonomy	*Task self-efficacy* How confident they were in their ability to exercise for 30 min when the exercise caused them to feel very good to very bad *Competence* Adapted from Intrinsic Motivation Inventory *Autonomy* Adapted from Intrinsic Motivation Inventory and	Inter-individual	• Pre-task self-efficacy positively correlated with FS during self-selected physical activity (r = 0.51, p = .003) and approached significance for prescribed physical activity (r = 0.34, p = .054) • Post-task competence positively correlated with FS during self-selected physical activity (r = 0.50, p = .004) and prescribed

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Table 1. Continued.

Reference	Country	Sample characteristics	Study design	Physical activity mode, length and intensity	Valence outcome	Mechanisms tested	Description of mechanism assessment	Level of analysis	Key findings
							Psychological Need Satisfaction in Exercise Scale		physical activity ($r = 0.35$, $p = .05$) • Autonomy was not correlated with FS during self-selected or prescribed physical activity
Schneider and Kwan (2013)	United States	182 adolescents Mean age = 14.8 ± 0.5 45% female	Experimental	Cycling ergometer 30-minutes 80% VT and midway point between VT and VO2peak	FS during physical activity (mins 10 & 20)	Motivation	Behavioural Regulations in Exercise Questionnaire	Inter-individual	• Intrinsic motivation was positively correlated with FS during physical activity and 80% VT ($r = 0.30$, $p < .003$) • Intrinsic motivation not correlated with FS during physical activity completed at an intensity between participant VT and VO2peak ($r = 0.17$, $p > .003$)
Shin et al. (2014)	South Korea	30 male physically active university students Mean age = 21.4 ± 1.6 0% female	Experimental	Running (indoor athletics track) 20-minutes 70–75% VO2max	FS during physical activity (mins 5, 10, 5 & 20)	Motivation	Intrinsic Motivation Inventory	Inter-individual	• Intrinsic motivation was positively related to the FS slope during exercise ($p = .04$)
Sudeck et al. (2016)	Switzerland	133 university staff Mean age = 49.5 ± 8.3 60% female	Experimental	Group exercise classes 60-minutes Self-paced	Valence subscale from the Multi-dimensional Mood Questionnaire during physical activity (mins 10 & 40)	Competence	'The feeling of being competent enough to fulfil the demands of the exercise session'	Inter- and intra-individual	• There was a positive intra-individual relationship between perceived competence and valence during physical activity ($p < .05$) • There was no inter-individual relationship between perceived competence and valence during physical activity ($p > .05$)

Turner and Stevinson (2017)	United Kingdom	22 running club members Mean age = 33.0 ± 8.3 36% female	Experimental	Running (treadmill and natural environment) 6000-m Self-paced (last 3000-m maximal effort)	FS during physical activity (3000 & 6000 m)	Physical environment	Indoors vs. natural environment	Intra-individual	• No difference in FS during physical activity completed outdoors and indoors (p>.03)
Vazou-Ekkekakis and Ekkekakis (2009)	Greece	19 female university students Mean age = 19 ± 2 100% female	Experimental	Walking/running (treadmill) 30-minutes Self-paced	FS during physical activity (mins 5, 10, 15, 20, 25 & 30)	Autonomy	Perceived locus of causality, volition, and perceived choice	Intra-individual	• No difference in FS during physical activity in the autonomous and control conditions (n.s.)
Welch et al. (2010)	United Kingdom	24 low physical activity female university student and staff Mean age = 23.0 ± 4.6 100% female	Experimental	Cycling ergometer 30-minutes 90% VT	FS during physical activity (mins 3, 6, 9, 12, 15, 18, 21, 24 & 27)	Task self-efficacy	Participants indicated their degree of confidence in their ability to cycle at a moderately fast pace without stopping for incremental intervals of 10, 20, 30, 45, and 60 min	Inter-individual	• Self-efficacy during physical activity was significantly related with FS during physical activity when the duration of the activity was unknown at 12–15 mins (R^2 = .208, p = .02) and 24–27 mins (R^2 = .293, p = .001) • Pre-task self-efficacy was not related with FS during physical activity when the duration of the activity was unknown at 12–15 mins (R^2 = .015, p = .558) and 24–27 mins (R^2 = .140, p = .062) • Pre-task self-efficacy was not related to FS during physical activity when the duration of the activity was known at 12–15 mins (R^2 = .002, p = .856) and 24–27 mins (R^2 = .050, p = .558) • Post-task self-efficacy was not related to FS during physical activity when the duration of the activity was known at 12–15 mins (R^2 = .060, p = .258) and 24–27 mins (R^2 = .150, p = .062)

Note: FS: Feeling Scale; HRR: heart rate reserve, HRmax: heart rate max; NR: not reported, VT: ventilatory threshold.

aerobically demanding exercise classes. They found that amotivation and externally regulated motivation were significantly negatively correlated to affective valence following the exercise class, whereas integrated and intrinsic motivation were significantly positively correlated with affective valence. In their study, Gillman and Bryan (2016) found that more playful motivations (i.e. feeling that you are in the moment, and doing what you are doing for its own sake) was positively correlated with more positive Feeling Scale score during physical activity completed at participant's ventilatory threshold (VT). In another study, young athletic males with higher intrinsic motivation for running had significantly greater positive trend in ratings on the Feeling Scale during a 20-minute running task completed at 70–75% of their $VO2_{max}$ (Shin et al., 2014). Additionally, in a study involving healthy adolescents, researchers found that intrinsic motivation, but not identified motivation, was positively related to pleasure during a MVPA task completed on a cycling ergometer at 80% of participant's VT (Schneider & Kwan, 2013). However, this study also found that neither intrinsic or identified motivation were related with pleasure when the activity was completed at an intensity between participant's VT and $VO2_{peak}$ (Schneider & Kwan, 2013).

Although there is consistent support that motivation explains inter-individual variance in the valenced response to MVPA, there is far more sparse support that motivation is a mechanism that may explain intra-individual variation in valenced responses to MVPA. One study found that within-person changes in motivational states toward more playful motivations (i.e. doing what you are doing for its own sake) was positively related to within-person changes in valence during an exercise task completed at participant's VT (Gillman & Bryan, 2016).

Competence and task self-efficacy

Findings generally supported the proposition that competence and task self-efficacy are mechanisms that explain inter-individual variance in the valenced response to MVPA. In support of the proposition, Rose and Parfitt (2012) found that pre-activity self-efficacy (measured before physical activity) and post-activity competence (measured retrospectively) were both significantly positively correlated with feelings of pleasure during a physical activity task completed at a self-selected intensity and at the participant's VT in a sample of active and inactive women. Another study found that task self-efficacy was positively correlated to changes in ratings of pleasure from immediately before to immediately following participation in group fitness class in a sample of young women with social physique anxiety (Raedeke et al., 2009). Likewise, a study involving adolescents aged 9–17 years found that there was a weak but significant relationship between pre-activity self-efficacy and feelings of pleasure during MVPA completed at 60% of participant's $VO2_{peak}$ (Robbins et al., 2004). Interestingly, another study found that post-activity self-efficacy, but not pre-activity-self efficacy, was positively correlated with Feeling Scale responses during a bout of stationary cycling at 60% of participant's $VO2_{max}$ in younger and older women (Barnett, 2013). Similarly, Welch et al. (2010) found that in-task self-efficacy but not pre-activity self-efficacy was associated with pleasure during a bout of stationary cycling at 90% of participant's VT, however, only when the duration of the physical activity was unknown. On the other hand, a study involving older and younger women found that neither pre-activity nor post-activity task self-efficacy were significantly correlated with feelings of pleasure while completing a MVPA task at 65% of participant's $VO2_{peak}$ (Focht et al., 2007). Similarly, Ekkekakis et al. (2010) found a weak and non-significant correlation between task self-efficacy and pleasure during a MVPA task completed at participant's VT in a sample of middle aged women. Additionally, Sudeck et al. (2016) found a non-significant between-person relationship between average level of perceived competence and affective valence reported during multiple group exercise classes.

There is sparse and inconsistent support that competence is a mechanism that explains intra-individual variation in valenced responses to MVPA. One study, which measured affective valence during group exercise sessions and perceived competence after each session on multiple occasions, found a significant within-person association between competence and affective valence during MVPA in a sample of university staff members (Sudeck et al., 2016). The authors found that when participants reported greater levels of perceived competence after an exercise session, they reported significantly greater levels of affective valence during the exercise session. Alternatively, in an experience sampling study involving older adults, Kanning and Hansen (2017) found that competence did not moderate the within-person association between physical activity and affective valence in daily life.

Autonomy

There is inconsistent support for the proposition that perceived autonomy explains the inter-individual variance in the valenced response to MVPA. In their experimental study, Rose and Parfitt (2012) found that there was no significant correlation between perceived autonomy and in-task responses on the Feeling Scale during self-selected or prescribed physical activities completed at participant's VT. Alternatively, a longitudinal diary study showed that autonomous orientations towards physical activity at baseline were positively related to valenced response to physical activity in daily life throughout the study period in a sample of undergraduate university students (Kwan et al., 2011).

There are also mixed findings regarding whether autonomy explains intra-individual variation in valenced responses to MVPA. In an experience sampling study, researchers found that autonomy moderated the within-person association between physical activity and affective valence in older adults (Kanning & Hansen, 2017). They found that when participants had autonomous orientation, there was a positive relationship between physical activity and valence, whereas when participants did not have an autonomous orientation, physical activity and affective valence were unrelated. In contrast, an experimental study involving young women, which compared the effects of self-selected and imposed physical activity at an identical intensity on pleasure, found that although participants reported significantly greater levels of perceived autonomy during self-selected physical activities, there were no differences in valenced response between the self-selected and imposed physical activity conditions (Vazou-Ekkekakis & Ekkekakis, 2009). Additionally, another ambulatory assessment study which examined the within-person moderating effect of autonomous regulations on the acute relationship between physical activity and affective valence in daily life found that although physical activity and autonomous orientations both had significant positive within-person associations with affective valence in a sample of university students, autonomous orientations did not augment the association between physical activity and valence (Kanning et al., 2012).

Relatedness and social context

There is mixed evidence regarding whether relatedness and the social context in which physical activities take place may be a mechanism that explains intra-individual variations in valenced response to MVPA. In a longitudinal study of participants in exercise classes, researchers found a significant positive within-person association between perceptions of the exercise group being an entity and affective valence during the exercise class (Graupensperger et al., 2019). Additionally, in their experimental study, Casado et al. (2019) found that young elite athletes gave significantly higher ratings on the Feeling Scale during high-intensity interval training sessions when completed in a group compared to when they completed them alone. However, participant's blood lactate concentration was significantly lower when participating in the group condition compared to the alone condition which may have confounded these results. Alternatively, in a sample of young women with higher than average levels of social physique anxiety, researchers found that participants reported significantly greater pleasure when exercising alone compared to exercising in public with others, even when controlling for perceived negative judgments by others about their physique (Focht & Hausenblas, 2006). Additionally, experience sampling studies have found that whether participants are alone or with someone else does not moderate the within-person relationship between physical activity and affective valence in samples of older adults (Cabrita et al., 2017; Kanning & Hansen, 2017).

Attentional focus

There is mixed support for attentional focus as a mechanism that may explain inter-individual variance in valenced response to MVPA. One study found that greater levels of associative thoughts during an incremental exercise task to exhaustion was negatively correlated with valence during physical activities completed at and above a participant's VT (da Silva et al., 2017). Another study found that dissociative thoughts were positively correlated with pleasure during physical activity completed at 5% above participants VT, but there was no correlation during physical activity completed at 10% below participant's VT (Jones et al., 2014). Additionally, a randomised trial found mixed support for attentional focus explaining inter-individual variations in the valenced response to MVPA (Gillman & Bryan, 2020). Researchers randomised participants into three groups (associative focus, mindfulness, distraction) and found that the distraction group reported more positive ratings on the Feeling Scale during physical activity than the associative focus group, however there was no difference between the distraction and mindfulness groups. Alternatively, Jones et al. (2017) found that associators reported significantly higher levels of pleasure following an exercise class compared to dissociators. In another study, researchers found that there was no difference in the valenced response to physical activities completed at 65–85% of participant's $HR_{reserve}$ between associators, dissociators, and people who switch between associative and dissociative attentional styles (Hutchinson & Karageorghis, 2013). Similarly, other studies have found no correlation between attentional focus and pleasure response to a graded physical activity task up to 65% of participants $HR_{reserve}$ (Cox et al., 2018) or self-paced walking (Krinski et al., 2017).

Results generally support attentional focus as a mechanism that may explain intra-individual variation in the valenced response to MVPA. Several experimental studies have used audio-visual stimuli (Bigliassi et al., 2019a; Hutchinson et al., 2015, 2017; Jones & Ekkekakis, 2019), music (Bigliassi et al., 2019b; Karageorghis & Jones, 2014), and exergaming (Glen et al., 2017) to successfully induce dissociative thoughts during MVPA. In each of these studies, researchers found that participants reported a more favourable valenced response to the MVPA tasks when completing the experimental condition that induced dissociative thoughts. Another study, which multiple experimental conditions, found mixed support for participants reporting more pleasure during conditions eliciting more dissociative attentional focus (Jones et al., 2014). Conversely, a single study used mindfulness stimuli to successfully induce associative thoughts, and found that participants had a more positive valenced response to the MVPA task when completing the experimental condition, where they had significantly more associative thoughts (Cox et al., 2018). Other experimental studies have successfully induced dissociative thoughts using audio-visual-stimuli (Bird et al., 2019), and music (Karageorghis et al., 2013), or used mindfulness stimuli to induce associative thoughts (Cox et al., 2019) during MVPA, however none of these studies observed significant intra-individual variance in affective valence outcomes between conditions.

Physical environment

One study examined whether the physical environment was a mechanism that explains inter-individual variation in the valenced response to MVPA. In their randomised controlled trial, Lacharité-Lemieux et al. (2015) found that participants completing exercise classes, consisting of a combination of aerobic and anaerobic activities, in an outdoor gym at a local park, reported significantly greater levels of affective valence during the classes, controlling for baseline valence, than those competing the classes in an indoor gym.

There has been a greater number of studies examining whether the physical environment explains intra-individual variance in valenced response to MVPA. Generally, research supports the physical environment being a mechanism that may explain intra-individual variance in the valenced response to MVPA. Studies have examined the effect of a number of outdoor environments, including parks and other natural environments (Niedermeier et al., 2017), athletics tracks (Dasilva et al., 2011; Krinski et al., 2017), and urban environments (Focht, 2009), and have all found that ratings of pleasantness was significantly greater when participants were walking outdoors compared to MVPA completed at a similar intensity indoors. Additionally, one study compared the valenced response to walking in natural and urban environments and found that participants reported the greatest pleasure when walking in natural environments (Kinnafick & Thøgersen-Ntoumani, 2014). Alternatively, some researchers have found that there is no difference in pleasure when active indoors compared to outdoors. In their study, Turner and Stevinson (2017), found that recreational runner's ratings of affective valence did not differ when completing a steady state running task in a natural outdoor environment or indoors on a treadmill. Another study found that although self-paced outdoor physical activities had a stronger positive effect on ratings on the Feeling Scale than self-paced indoor physical activities during exercise in a sample of mental health inpatients, the effect was not statistically significant (Frühauf et al., 2016). Additionally, another study found that active older adults reported similar levels of pleasantness during physical activity completed indoors, at an athletics track, and at the beach (De Brito Farias et al., 2018).

Discussion

This narrative literature review summarised evidence relating to mechanisms that may explain inter- and intra-individual variation in the valenced response to MVPA. The breadth of studies in recent years highlights the growing research interest into factors that explain difference in the valenced response to MVPA between and within individuals.

Research generally supports attentional focus and the physical environment as mechanisms that explain intra-individual variation in the valenced response to MVPA. Findings of these studies suggest that people will have a more positive valenced response to MVPA when they have dissociative thoughts (i.e. focusing on the external stimuli rather than bodily sensations). Given that studies included in this review have successfully used audio-visual stimuli (Bigliassi et al., 2019a; Hutchinson et al., 2017; Jones & Ekkekakis, 2019; Jones et al., 2014), and gamification (Glen et al., 2017) to induce dissociative thoughts and improve affective valence outcomes, using virtual reality may have the potential to increase pleasurable feelings during MVPA. Additionally, game-based mobile phone applications, which may be more accessible than virtual reality, also have the potential to induce dissociative thoughts during MVPA (Gillman & Bryan, 2016), as does listening to upbeat music (Bigliassi et al., 2019b). Therefore, it may be possible to utilise mobile and wearable technologies during MVPA to make it a more pleasurable experience. However, it is important to note that there are several intermediaries such as the motivational quality of a stimuli and an individual's associations with stimuli that may influence whether it will lead to dissociative thoughts and a more pleasurable experience when physically active (Karageorghis & Priest, 2012). If an individual has a negative evaluation of a stimuli or dislikes a stimuli, it may have the potential to decrease pleasure (Juslin, 2013).

The results also showed that people generally have a more pleasurable experience when participating in MVPA outdoors compared to indoors. This is consistent with findings that being physically active in natural environments may have added benefits for an individual's wellbeing (Bowler et al., 2010; Thompson Coon et al., 2011). This may be explained by people having greater levels of dissociation outdoors (Krinski et al., 2017) and is in accordance with the attention restoration theory, which suggests that fascinating natural environments can easily hold an individual's attention (Kaplan, 1995). The attention restoration theory also explains why ratings of pleasantness are greater when active in natural environments than urban environments (Kinnafick & Thøgersen-Ntoumani, 2014). Natural environments are likely to have a greater array of external stimuli that can grab someone's attention and induce dissociative thoughts than urban environments. Concerningly, as society becomes more urbanised, there is a decline in opportunities for individuals to interact with nature (Soga & Gaston, 2016). However, exposure to urban green spaces may have similar positive impacts on moods and emotions to natural environments (Kondo et al., 2018). Therefore, the provision of urban green spaces such as parks and other open space with natural features and facilities to support MVPA is important to enable pleasurable MVPA experiences. Additionally, it may be beneficial to allow physical activity providers to deliver their programmes at public open spaces to improve the participants experience and adherence to physical activity programmes (Focht & Hausenblas, 2006; Lacharité-Lemieux et al., 2015).

While intra-individual variation in the valenced response to MVPA appears to be at least partly explained by external stimuli that effect attentional focus, the findings of this review suggest that cognitive factors may explain inter-individual variations in the valenced response to MVPA. This is consistent with the propositions of the dual-mode model, which suggests that cognitive factors have the strongest influence over the valenced response to MVPA (Ekkekakis et al., 2005b). Motivation, competence and task self-efficacy may explain inter-individual variation in the valenced response to MVPA. A consistent finding was that people who are intrinsically motivated to be physically active will likely find MVPA a more pleasurable experience. This is aligned with the self-determination theory (Deci & Ryan, 1985), which suggests that intrinsic motivation to be physically active will lead to greater-wellbeing than extrinsic motivation, even when extrinsic aspirations are achieved (Ryan et al., 2009). Therefore, framing MVPA as enjoyable may lead to a more pleasurable experience than encouraging people to participate in MVPA to achieve extrinsic aspiration such as improving physical appearance or losing weight. For example, focusing on obesity prevention and treatment, rather than the other benefits of MVPA, may have the potential to lead to a less pleasurable experience when physically active.

Evidence also generally supported that people with greater competence or task-self-efficacy had greater valenced responses to MVPA. However, the findings suggest that the timing of appraisals of competence and self-efficacy is important. For example, one study found that in-task self-efficacy, but not pre-task self-efficacy, was related to valenced responses MVPA (Welch et al., 2010). Similarly, another study found that post-task self-efficacy, but not pre-task self-efficacy, was related to pleasure during MVPA (Barnett, 2013). This suggests that there may be a reciprocal relationship between pleasure and self-efficacy, where pleasure during physical activity predicts appraisals of self-efficacy. Additionally, the relationship between self-efficacy and valence may be stronger when individuals have a more temporally prominent experience on which to base appraisals of self-efficacy (Welch et al., 2010). Therefore, appraisals of self-efficacy and competence may change throughout the course of participating in physical activities. It may be important to consider how individuals can use perceptions of ability to regulate physical activities so that they are optimally challenging, which is likely to lead to a more pleasurable experience.

The majority of the findings reported in this review are based on healthy adult populations. However, younger populations may have greater intention behaviour dissonance (Downs & Hausenblas, 2005), which could potentially be accounted for by affective judgements towards MVPA (Rhodes & de Bruijn, 2013b; Rhodes & Yao, 2015). This is because instrumental attitudes may be based on perceptions of long term benefits of participation in physical activity whereas affective attitudes may be based on more immediate benefits of participation in physical activity (Morris et al., 2016). Therefore, affective attitudes may operate in the short term and influence more proximal behaviours than instrumental attitudes. Future research should aim to understand factors that may explain inter- and intra-individual variation in the valenced response to MVPA in children and adolescents. It may also be valuable to research factors that may explain variation in the valenced response to MVPA in groups of individuals who are particularly averse to MVPA, such as people with overweight or obesity (Ekkekakis et al., 2016). Additionally, future research should consider the possibility of interactions between multiple factors in determining the valenced response to physical activity. For example, limited research suggests that multiple cognitive (Jones et al., 2017) and contextual factors (Johansson et al., 2011) may interact to influence an individual's experience when physically active.

There are also some methodological considerations to consider. Most of the evidence identified in this review is based on experimental studies completed in controlled laboratory settings. Although this provides the advantage of studying mechanisms while controlling for confounding variables, conducting experiments in such settings precludes researchers from ascertaining context specific associations that only occur in real world settings (Reis, 2012). Future research should prioritise daily life methodologies that examine moderators of the acute association between MVPA and valence *in situ*.

Another methodological consideration is the heterogeneity in prescribed intensity of physical activities in the included studies. Only half of the included experimental studies controlled for exercise intensity, whereas the other half instructed participants to self-pace their physical activity. Research has shown that although when instructed to exercise at a self-selected speed, individuals will on average select an intensity slightly below their VT (Ekkekakis & Lind, 2006; Lind et al., 2005, 2008), there is heterogeneity in the intensity selected by individuals. For example, Lind et al. (2005) found that when instructed to exercise at a self-selected intensity, individual participants picked intensities ranging from 67–83% HR_{max}, similar to the range observed in an earlier study of 51–89% of HR_{max} (Spelman et al., 1993). Therefore, while some participants chose an intensity at the lower limits of moderate intensity, others are exercising at an intensity considered vigorous (Norton et al., 2010). Given that experimental studies have the advantage of controlling for confounders, future experimental studies should control for physical activity intensity.

Although this article provides an extensive overview of mechanisms which may explain inter- and intra-individual variations in the valenced response to MVPA, there are some limitations that must be considered. First, the review process was completed by a single author which has the potential to introduce individual biases. Second, the scope of the review and the diversity of methods of the included studies precluded a systematic or meta-analytic approach to this review. Additionally, this review analysed results of included studies based on levels of statistical significance. Therefore, the conclusions of this study have the potential to be biased as a result Type II error from the inclusion of studies with low statistical power. Additionally, analysing results based on statistical significance gives the same weight to all included studies regardless of sample size and does not take make an effect size estimate. Finally, only hypothesised mechanisms, including those from the self-determination theory, the social context and the physical environment were included in this review. Therefore, other potential mechanisms that may explain variance in the valenced response during MVPA may not have been included.

Conclusion

This narrative review provides an overview of hypothesised mechanisms that may explain the variance in the valenced response during MVPA. Consistent with the dual-model, evidence supports the proposition that individual cognitive factors may explain inter-individual variability in the valenced response to MVPA. Specifically, motivation, competence and task self-efficacy appear to somewhat explain why individuals differ in their valenced response to MVPA. Additionally, results suggest that completing MVPA outdoors and inducing dissociative thoughts may lead to a more positive valenced response to MVPA within individuals. Therefore, environmental stimuli that may produce an external attentional focus may lead to a more pleasurable experience when participating in MVPA. More research examining factors that may explain variance in the affective response to MVPA in younger populations and populations that are particularly averse to MVPA is required. Additionally, research should prioritise daily life methodologies to examine the relationship between MVPA and valence in ecologically valid settings, and experimental studies should control for physical activity intensity.

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ORCID

Melinda Craike http://orcid.org/0000-0002-7374-1286

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Review

A systematic review of the within-person association between physical activity and affect in children's and adolescents' daily lives

Matthew Bourke[a,*], Toni A. Hilland[b], Melinda Craike[a,c]

[a] Institute for Health and Sport (IHES), Victoria University, PO Box 14428, Melbourne, Victoria, 8001, Australia
[b] School of Education, College of Design and Social Context, RMIT, PO Box 71, Bundoora, Victoria, 3083, Australia
[c] Australian Health Policy Collaboration, Victoria University, PO Box 14428, Melbourne, Victoria, 8001, Australia

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ABSTRACT

Background: It is important to understand the relationship between physical activity and affect because affect experienced during physical activity and momentary incidental affect may both predict physical activity behaviours. Additionally, affect experienced during physical activity may explain the mental health benefits of participation in physical activity. Utilising ambulatory assessment techniques, researchers can examine the acute within-person association between physical activity and affect in children and adolescents' daily life. The purpose of this study was to systematically review the literature to determine whether there is a within-person association between physical activity and affect in children and adolescents' daily life.
Methods: Medline via EBSCOHost, SPORTdiscus, PsychINFO, and Scopus were searched up to March 2020. A narrative synthesis was used to summarise results of the included studies.
Results: Ten studies, reporting on nine unique samples, met the inclusion criteria. The strongest evidence identified was for a positive within-person association between physical activity and subsequent positive affect and energy. The findings regarding the within-person association between physical activity and subsequent negative affect and moods were mixed, as were the findings regarding affect predicting subsequent physical activity.
Conclusion: There was mixed support for the acute within-person association between physical activity and affect in children and adolescents. Future research should consider factors that may moderate the relationship between physical activity and affect. Additionally, experimental research should examine how manipulations of incidental affect effect physical activity participation in children and adolescents' daily life.
Prospero Registration: CRD42020141649.

1. Introduction

There is extensive evidence linking physical activity to positive physical, mental and cognitive health outcomes in children and adolescents (Biddle, Ciaccioni, Thomas, & Vergeer, 2019; Poitras et al., 2016). Despite the health benefits of physical activity, very few children and adolescents worldwide are sufficiently physically active (Tremblay et al., 2016). Global estimates suggest that fewer than 20% of adolescents accumulate 60 min of moderate-to-vigorous physical activity (MVPA) each day of the week (Guthold, Stevens, Riley, & Bull, 2019). Additionally, research suggests that levels of physical activity begin to decline during childhood and continue to decline throughout adolescence (Corder et al., 2019; Farooq et al., 2018). Therefore, increasing levels of physical activity in young people is a global public health priority (World Health Organization, 2018).

The most prominent theoretical approaches to understanding determinants of participation in physical activity have fallen within the social-cognitive archetype (Rhodes, McEwan, & Rebar, 2019). Prominent models include the Social-Cognitive Theory (Bandura, 1986), and the Theory of Reasoned Action/Planned Behaviour (Ajzen, 1985). These models are based on the premise that people make conscious plans or form intentions to participate in behaviours based on psychological and social factors, and that people self-regulate their behaviours in to realise these plans or intentions. Although social-cognitive determinants of physical activity have been extensively studied in children and adolescents, results from a meta-analysis suggested that only 33% of the variance in adolescent's physical activity participation was explained by social-cognitive constructs (Plotnikoff, Costigan, Karunamuni, &

* Corresponding author.
E-mail addresses: matthew.bourke6@live.vu.edu.au (M. Bourke), toni.hilland@rmit.edu.au (T.A. Hilland), melinda.craike@vu.edu.au (M. Craike).

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Lubans, 2013). Another popular framework through which to examine correlates of physical activity is the Self-Determination Theory, which has been used to assess the association between motivation, basic psychological needs and physical activity (Ryan & Deci, 2000). However, again, the constructs from the self-determination theory have been found to only have a weak association with physical activity in young people (Owen, Smith, Lubans, Ng, & Lonsdale, 2014).

Given the modest association of constructs from social-cognitive models and the Self-Determination theory with physical activity, more recently attention has been given to the relationship between affect and physical activity (Ekkekakis, Hargreaves, & Parfitt, 2013). There are multiple ways in which affect is conceptualised including core affect, moods, and emotions. Core affect is defined as "the most elementary consciously accessible affective feelings … that need not be directed at anything" (Russell & Barrett, 1999, p. 806). Core affect is theorised to consist of two orthogonal and bipolar dimensions: valence (i.e., pleasure - displeasure), and energetic arousal (i.e., activation – deactivation) (Russell, 1980). Based on a 45-degree rotation of these dimensions, core affect can also be conceptualised as changes in positive activated states (also referred to as positive affect; e.g. interested, excited) and negative activated states (also referred to as negative affect; e.g., distressed, upset) (Watson & Tellegen, 1985). Core affect is a broader construct than emotion or mood, and it may be perceived as unattributable (Biddle, Mutrie, & Gorely, 2015; Russell & Barrett, 1999).

Whereas core affect may be unattributable, moods and emotions are a result set of interrelated sub events concerned with a specific phenomenon, including cognitive appraisals of the phenomenon, changes in core affect and physiological adaptations (Kleinginna & Kleinginna, 1981). Additionally, moods and emotions may lead to expressive and adaptive changes in behaviours (Kleinginna & Kleinginna, 1981). The distinction between emotions and moods is less clear but can be considered in terms of intensity and length (Ekkekakis, 2013). Emotions are more intense and last or a shorter duration, whereas moods are less intense and last for a longer duration (Ekkekakis, 2013). Core affect, moods and emotions represent the hierarchical structure of affect; core affect represents higher order dimensions that account for overlapping commonalities between lower order discrete moods and emotions (Ekkekakis & Petruzzello, 2000; Watson & Clark, 1997).

The theory of hedonic motivation provides a framework to understand how affect experienced during physical activity will influence future physical activity participation (Williams, 2018). It states that pleasure or displeasure experienced during a behaviour is associated with future hedonic motivation for that behaviour (i.e. desiring or dreading it) (Williams, 2018). Consistent with dual-process models, it is suggested that this hedonic motivation is triggered automatically by a behavioural cue (e.g. seeing a pair of running shoes). Therefore, how much pleasure young people experience during physical activity will determine how much they desire or dread participating in physical activities in the future. Hedonic motivation is hypothesised to be the outcome of automatic affective evaluations, or implicit attitudes (Williams & Evans, 2014; Williams, Rhodes, & Conner, 2019). Implicit attitudes are the automatic evaluations of the goodness or badness of physical activity (Ekkekakis & Brand, 2019). These implicit attitudes are formed through lived experiences, therefore the core affects, moods and emotions repeatedly experienced while physically active will determine young peoples' implicit attitudes (Brand & Ekkekakis, 2018; Conroy & Berry, 2017; Ekkekakis & Brand, 2019). In addition to being an antecedent of hedonic motivation, implicit attitudes are also suggested to effect physical activity behaviours through thwarting or augmenting behavioural intentions derived from reflective processes (Rhodes & Gray, 2018). Empirical evidence shows that implicit attitudes have a small but significant association with physical activity (Chevance, Bernard, Chamberland, & Rebar, 2019). Importantly, implicit attitudes are associated with physical activity independently of reflective processes including behavioural intention, perceived self-efficacy, behavioural control, barriers, and outcome expectations (Conroy, Hyde, Doerksen, & Ribeiro, 2010). The influence of implicit attitudes on physical activity participation may be particularly important in children and adolescents, who typically have less volition over physical activity behaviours than adults (Downs & Hausenblas, 2005). Consistent with the theory of hedonic motivation, empirical evidence has consistently shown that affect experienced during physical activity predicts future physical activity participation (Rhodes & Kates, 2015). Therefore, understanding how young people experience affect during physical activity may help explain why they are physically active and their levels of engagement in physical activity.

As well as having the potential to predict future physical activity participation through implicit attitudes and hedonic motivation, affect experienced during physical activity is hypothesised to be a mechanism that may explain the association between physical activity and mental health outcomes in young people (Lubans et al., 2016). Potential improvements in affect associated with participating in physical activity, or the "feel better" effect, helps explain how physical activity may prevent or treat common mental health disorders including anxiety and depression (Ekkekakis et al., 2013). Therefore, understanding the affect that children and adolescents experience during physical activity may also help understand the mental health benefits of participation in physical activity in young people.

In addition to physical activity related affect, incidental momentary affect may also influence whether someone participates in physical activity or not (Williams et al., 2019; Williams & Evans, 2014). Whereas physical activity related affect is affiliated with physical activity behaviours, be it anticipatory, during, or following physical activities, incidental affect is not directly related to physical activity behaviours, but may nevertheless influence the behaviour (Williams et al., 2019). Negative incidental affect might lead to more maladaptive behaviours and decrease the likelihood of participating in target behaviours (Williams & Evans, 2014). Alternatively, positive incidental affect is associated with increased engagement with positive goals and could therefore increase the likelihood of participating in health behaviours, including physical activity (Williams & Evans, 2014). For example, Maher et al. (2017) found that adults were significantly more likely to follow through on intentions to be physically active when they were experiencing more positive incidental affect, and less likely to follow through on intentions to be physically active when they were experiencing more negative incidental affect. Thus, in addition to physical activity related affect, it is important to consider the impact of incidental momentary affect on young people's participation in physical activity.

Traditionally, cross-sectional, longitudinal, and experimental studies have been used to examine the bidirectional relationship between physical activity and affect (Dunton, 2017). However, experimental research is conducted in controlled laboratory settings and therefore lack ecological validity and cannot ascertain context specific associations that may only occur in real world settings (Reis, 2012). Furthermore, it is not possible to determine whether incidental affect is associated with greater levels of physical activity in laboratory studies. Additionally, although cross-sectional and longitudinal research can provide an understanding of the relationship between physical activity completed in daily life and affect, they measure behaviours infrequently, and therefore can only explain trait level relationships at a between-person level (e.g. do young people who are more active on average experience more positive affect?). Therefore, it is not possible to examine acute within-person, or state level, associations in daily life using traditional methodologies (e.g. do young people experience more positive affect when they are more physically active than they usually are?) (Kanning, Ebner-Priemer, & Schlicht, 2013). This has important implications for the understanding of the relationship between physical activity and affect. Examining relationships solely at a between-person level fails to account for the temporal (i.e. time specific) and spatial (i.e. context specific) synchronicity between physical activity and affect (Dunton, 2017). This is a particularly important limitation when researching the relationship between PA and affect, both of which are dynamic and fluctuate frequently through time and space (Dunton, 2017; Trull, Lane, Koval, & Ebner-Priemer, 2015). Additionally, it is possible that the within- and between-person associations will vary in magnitude or even direction. Therefore, within-person inferences cannot be drawn from between-person analyses and to do so is to commit an ecological fallacy (Dunton, 2017; Kanning et al., 2013; Reichert et al., 2020). For example, when examining the effects of physical activity on blood pressure, there is a positive within-person association between physical activity and blood pressure such that people have higher blood pressure when they are more active than usual, however, there is a negative between-person association between physical activity and blood pressure such that people who are more active than others on average have lower blood pressure (Reichert et al., 2020).

To examine within-person associations between physical activity and affect in daily life, researchers can use ambulatory methods that measure behaviours and affect during daily life, such as daily diaries or ecological momentary assessment (EMA) (Trull & Ebner-Priemer, 2013). EMA uses real-time data capture strategies that can measure an individual's physical activity and affect as they occur in naturalistic settings, multiple times each day (Shiffman, Stone, & Hufford, 2008). Therefore it is possible to determine temporally and contextually synchronous covariances between physical activity and affect using these methods. A systematic review published in 2015 of ambulatory assessment studies in all age groups found mixed evidence supporting a bidirectional relationship between physical activity and affect in daily life (Liao, Shonkoff, & Dunton, 2015). However, this review only included a single study on children or adolescents. More recently, there has been an increase in the number of studies using EMA in physical activity research (Degroote, DeSmet, De Bourdeaudhuij, Van Dyck, & Crombez, 2020). Despite this increase in research interest, and our growing understanding of the importance of affect in determining participation in physical activity, to date no studies have synthesised research on the relationship between physical activity and affect in daily life in young people. Therefore, the purpose of this paper is to conduct an up to date systematic review to determine whether there is a within-person association between physical activity and affect in children and adolescent's daily life.

2. Methods

This review was registered with PROSPERO (CRD42020141649). A search was conducted on four electronic databases (Medline via EBSCOHost, SPORTdiscus, PsychINFO, and Scopus) up to March 2020. Searches were restricted to title, abstract and keywords. The search strategy included terms for: 1) physical activity ("physical activit*" OR exercis*); 2) affect (affective state*" OR "positive affect" OR "negative affect" OR affectivity OR hedonic OR hedonism OR valence* OR arousal OR calm* OR vigour OR vigor OR mood* OR emotion* OR "feeling state*" OR psychological OR pleasure); 3) the population of interest (child OR children OR adolescen* OR "young people" OR "young person" OR student* OR teenager*); and 4) assessment technique ("ecological momentary assessment" OR ema OR "experience sampling" OR "event contingent" OR esm OR "ambulatory assessment" OR "daily diary" OR "intensive longitudinal" OR "natural* observation" OR "daily life" OR "everyday life" OR "within-individual" OR "within-person"). Additionally, reference lists of all included papers were manually checked to identify any additional relevant articles not identified in the electronic search.

2.1. Inclusion and exclusion criteria

To be included in this review, studies had to: 1) examine the within-person association between physical activity and affect, moods or emotions in daily life; and 2) include participants with an average age between 5 and 18 years. Studies were excluded if: 1) they only examined the between-person association between physical activity and affect, moods or emotions; 2) they examined the within-person association between physical activity and moods or affect in experimental or controlled settings; and 3) participants average age was <5 years or >18 years.

2.2. Identification of eligible studies

Two individual reviewers (a PhD candidate and a PhD) independently scanned all eligible titles and abstracts and removed articles beyond the scope of the review. Next, two reviewers (a PhD candidate and a PhD) independently reviewed full texts of each potentially relevant article against the inclusion and exclusion criteria. Disagreements between reviewers were resolved through discussion with a third reviewer (a PhD) until a consensus was achieved.

2.3. Data extraction

Data extraction was completed by a single reviewer and checked by two independent reviewers. In the situation that the independent reviewer highlighted a discrepancy between extracted data and data in the original article, data was reextracted to ensure accuracy. Data was extracted for study setting, participant demographics, study design and procedures, measurement of affect, measurement of physical activity, model covariates and moderators, and within-person relationships between physical activity and affect.

2.4. Quality assessment

Quality of included studies was assessed using the National Heart, Lung, and Blood Institute Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (National Institutes from Health, 2014). Items that were not applicable to EMA and daily diary studies were removed (i.e. were the outcome assessors blinded to the exposure status of participants?; was the exposure(s) assessed more than once over time?). Additionally, an item was changed from retention rate to compliance rate.

3. Results

The literature search yielded a total of 825 potentially relevant articles; 789 were removed based on title or abstract and 36 full texts were retrieved. After full text screening, nine relevant articles were identified. One additional article was identified after manually checking the reference list of relevant studies. In total, ten studies, reporting on nine unique samples, met the inclusion criteria (Fig. 1).

3.1. Study characteristics

A detailed overview of the characteristics of each study is in Table 1. Five studies were conducted in the United States, while the remaining five studies were conducted in Germany. Seven studies included adolescents, two studies included older children (aged 8–12 years) and the remaining three studies included a combination of older children and adolescent (aged 9–13 years). Overall, four studies examined the bidirectional relationship between physical activity and affect, four studies only examined physical activity as a predictor of affect, and two studies only examined affect as a predictor of physical activity. The majority (k = 8) of studies utilised EMA techniques to measure affect, while two studies used daily diaries. All studies that utilised EMA used electronic devices (e.g., mobile phones) to survey participants. The two diary studies gave participants the option to complete the diary electronically or using paper-and-pencil. All but one study used device-measured physical activity (accelerometery k = 8; pedometer k = 1). The one study employing self-report was an EMA study and asked participants to report the activity that they were participating in at the time they

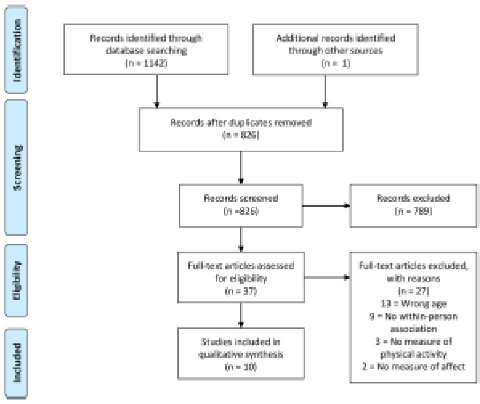

Fig. 1. PRISMA flow diagram of articles screened and retrieved.

received the prompt. To measure affect, four studies used items from the Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988), three studies used items from the Profile of Mood States (McNair, Lorr, & Droppleman, 1971), one study based their items on the Multi-Dimensional Mood Questionnaire (Wilhelm & Schoebi, 2007), and four studies used self-developed items.

3.2. Quality assessment

Study quality is reported in Table 2. All studies had a clearly defined research question or objective and study population. Only a single study reported a response rate; most studies used self-referral methods to recruit participants meaning that response rates could not be calculated. Over half of included studies (k = 6) had clear inclusion and exclusion criteria that were applied uniformly to all participants. Only a single study provided details of a post-hoc power analysis and no studies provided a-priori justification of their sample size. All but one study used reliable and validated measures for physical activity, however less than half (k = 4) of the included studies used validated measures for affect. Additionally only two studies (on the same population) reported a compliance rate over 80%. Finally, all but one study controlled for potential level-1 confounders.

3.3. Physical activity as a predictor of affect in daily life

Eight studies examined physical activity as a predictor of affect or mood in daily life. Six of these were EMA studies (Cushing, Bejarano, Mitchell, Noser, & Crick, 2018; Cushing et al., 2017; Dunton et al., 2014; Kolar et al., 2020; Kühnhausen, Leonhardt, Dirk, & Schmiedek, 2013; Wen et al., 2018), and two were daily diary studies (Gawrilow, Stadler, Langguth, Naumann, & Boeck, 2016; Langguth, Schmid, Gawrilow, & Stadler, 2016). Five studies included accelerometer measured MVPA accumulated in windows ranging from the 30-min prior to a prompt to daily levels of MVPA as a predictor (Cushing et al., 2018, 2017; Dunton et al., 2014; Langguth et al., 2016; Wen et al., 2018), one study used the total amount of accelerometer measured physical activity in the 30-min prior to a prompt as a predictor (Kolar et al., 2020), one study included the percentage of day spent in accelerometer measured MVPA as predictors (Kühnhausen et al., 2013), and a single study used pedometer measured daily steps as a predictor (Gawrilow et al., 2016). The affect outcomes measured were positive and negative affect (Cushing et al., 2017; Dunton et al., 2014; Kolar et al., 2020; Wen et al., 2018), energy (Cushing et al., 2017; Dunton et al., 2014), tired or fatigued (Cushing et al., 2017; Dunton et al., 2014), pleasantness and unpleasantness (Kühnhausen et al., 2013), activation and deactivation (Kühnhausen et al., 2013), depressed mood (Cushing et al., 2018; Gawrilow et al., 2016; Langguth et al., 2016), anger (Cushing et al., 2018), and anxiety (Cushing et al., 2018).

Of the four studies reporting positive affect as an outcome, all were EMA studies. Three studies examined the relationship between device-measured MVPA accumulated in the 30-min before an EMA prompt and subsequent positive affect and all found a significant positive relationship (Cushing et al., 2017; Dunton et al., 2014; Wen et al., 2018). Additionally, a single study which examined the relationship between total device-measured physical activity in the 30-min before an EMA prompt and subsequent positive affect also found a significant, positive relationship (Kolar et al., 2020). However, a single study found a non-significant relationship between device-measured MVPA accumulated in the 60-min prior to an EMA prompt and subsequent positive affect (Wen et al., 2018). Additionally, single study that aggregated EMA responses throughout the day found a non-significant within-person association between the percentage of the day spent in MVPA or vigorous physical activity with aggregate levels of pleasantness reported throughout the day (Kühnhausen et al., 2013).

All four studies reporting negative affect as an outcome were EMA studies. Three studies found a non-significant within-person associations between the amount of time spent in device-measured MVPA in the 30-min prior to a prompt and subsequent negative affect (Cushing et al., 2017; Dunton et al., 2014; Wen et al., 2018). The same result was observed when examining the association between MVPA in the 60-min prior to a prompt and subsequent negative affect (Wen et al., 2018). Additionally, a single study examined the association between total device-measured physical activity in the 30-min prior to a prompt and subsequent negative affect in a sample of female adolescents with and without anorexia nervosa (Kolar et al., 2020). Results showed that there was no statistically significant main effect of physical activity on negative affect. However, there was a statistically significant moderating effect, which indicated that physical activity was negatively associated with negative affect in participants affected by anorexia nervosa but not participants who were not affected by anorexia nervosa. Additionally, a single study found a non-significant within-person association between the percentage of the day spent in moderate or vigorous physical activity with aggregate levels of unpleasantness reported throughout the day (Kühnhausen et al., 2013).

Of the three studies reporting findings on depressed mood as an outcome, one was an EMA study and two were daily diary studies. The EMA study found that MVPA accumulated in the 30-min before the EMA prompt did not have a significant within-person association with subsequent depressed mood (Cushing et al., 2018). One diary study found accumulating more steps during the day than usual was related to lower levels of depressed mood in the evening in a sample of children with symptoms of attention-deficit hyperactivity disorder (Gawrilow et al., 2016). Additionally, results showed that this association was stronger in children with more severe hyperactivity. Another diary study found a non-significant within-person association between MVPA accumulated throughout the day and same evening depressed mood, however participating in greater levels of MVPA throughout a day was related to lower levels of depressed mood the following morning (Langguth et al., 2016). Results showed this relationship was stronger in young women and on weekdays. Additionally, one EMA study found a non-significant within-person association between MVPA accumulated in 30-min before a prompt and subsequent feelings of anger and anxiety (Cushing et al., 2018).

Two EMA studies found a significant positive within-person association between MVPA in the 30-min before a prompt and subsequent energy (Cushing et al., 2017; Dunton et al., 2014). However, one study that aggregated EMA responses throughout the day found a non-significant within-person association between the percentage of the day spent in moderate or vigorous physical activity with aggregate

Table 1 (*continued*)

Author (year of publication)	Country, setting & study name	Recruitment strategy	Demographic information		Population	Design/Procedures	Compliance rate	Measure of affect	Measure of physical activity	Statistical analysis
			n (% female)	Mean age (SD)						
						and-paper version of the diary.				Moderators: Hyperactivity
Koch et al. (2018)	Germany Public URGENCY study	Not reported	113 (48%)	15.02 (1.70)	Healthy	Electronic EMA. Between 4 and 7 prompts on weekdays and 8–17 prompts on weekends over 7 consecutive days. Prompts were GPS triggered when participants passed a distance over 0.5 km plus two prompts that occurred at fixed times each day.	M = 82% (SD = 14.23%)	Based on the Multi-Dimensional Mood Questionnaire. Valence was measured with 9 items: *cheerful, content, delighted, fantastic, good, afraid, mad, miserable, unhappy*. Energetic arousal was measured with 6 items: *active, concentrated, interested, exhausted, faint, tired*. Calmness was measured with 5 items: *pleasant, rested, anxious, on edge, stressed*	Accelerometer (Move-II/III) measured minutes of non-exercise physical activity in the 10-min after each EMA prompt. Exercise was assessed by participant self-report after the conclusion of the monitoring period and excluded from analyses.	Direction: Affect → Physical activity Level-1 covariates: Time of day
(Kolar et al., 2020)	Germany Specialised treatment centre for eating disorders	Participants with anorexia nervosa (AN) recruited at the beginning of inpatient treatment at a specialised treatment centre for eating disorders. Participants without AN recruited via word-of-mouth	62 (100%)	16.18 (1.62)	Healthy and anorexia nervosa	Electronic EMA Prompts sent hourly over a single day between 7am and 11pm	56.4%	PANAS-X Positive affect was measured with 8 items: *strong, enthusiastic, proud, attentive, happy, energised, confident and cheerful* Negative affect was measured with 8 items: *nervous, disgusted, distressed, ashamed, angry at self, afraid, sad, and dissatisfied with self*	Accelerometer (SOMNO-watch™) measured minutes of physical activity in 30-min prior to each prompt.	Direction: Physical activity → Affect Level-1 covariates: Time, ambient temperature Moderators: AN
(Kühnhausen et al., 2013)	Germany School FLUX study	Convenience sample of students from threes third grade and three fourth grade classes.	82 (45%)	9.77 (0.62)	Healthy	Electronic EMA. 4 prompts each day over a 4-weeks.	Average of 17 of 28 days valid data (61%)	12 items used to measure pleasantness (3 items), unpleasantness (3 items), activation (3 items), and deactivation (3 items). Measurements were made 4-times a day and aggregated into a single daily score for each factor.	Percentage of day spent in accelerometer (ActiGraph GT3X+) measured MVPA and VPA.	Direction: Physical activity → Affect Level-1 covariates: Time
(Langguth et al., 2016)	Germany School	Convenience sample of participants from two public secondary schools and one vocational college.	72 (37%)	17.36 (3.38)	Healthy	Daily diary completed over 7 days. Participants could opt to complete an electronic or pen-and-paper version of the diary.	Not reported	Depressed affect measured with 3 items from the POMS: *sad, discouraged, hopeless.*	Accelerometer (ActiGraph GT3X+) measured daily minutes of MVPA.	Direction: Physical activity → Affect Level-1 covariates: Accelerometer wear time, study day, weekend Moderators: Sex, weekend

(*continued on next page*)

Table 1 (*continued*)

Author (year of publication)	Country, setting & study name	Recruitment strategy	Demographic information: n (% female)	Demographic information: Mean age (SD)	Population	Design/Procedures	Compliance rate	Measure of affect	Measure of physical activity	Statistical analysis
(Rusby et al., 2014)	United States School	Convenience sample of students from four middle schools.	82 (51.22%)	Not reported (Described as seventh and eighth grade students)	Healthy and at risk youths	Electronic EMA. Between 3 and 4 prompts on weekdays outside of school hours and 5–6 prompts on weekends over 7 consecutive days.	M = 69.44%	A single item to measure happiness.	Self-reported physical activity. Participants asked to report activities that they were doing at the time of the prompt (0 = not participating in physical activity and 1 = participating in physical activity)	Direction: Affect → Physical activity Level-1 covariates: Presence of peers, weekend Moderators: Gender
(Wen et al., 2018)	United States Public MATCH study	Self-referred from informational flyers and in-person research staff visit to public elementary school and community event	202 (50.99%)	9.61 (0.91)	Healthy	Electronic EMA. Up to 28 total prompts over 8 days.	M = 74.43% (SD = 19.89%)	Items based on the PANAS-C. Positive affect was measured with two items: *happy, joyful*. Negative affect was measured with three items: *stressed, sad, mad*.	Accelerometer (ActiGraph GT3X) measured minutes of MVPA in the 30 and 60 min before and after each EMA prompt.	Direction: Bidirectional Level-1 covariates: n-1 affect/activity Moderators: Perceived stress

levels of activation reported throughout the day (Kühnhausen et al., 2013). Additionally, EMA studies found a non-significant within-person association between MVPA in the 30-min before a prompt and subsequent feelings of tiredness (Dunton et al., 2014) and fatigue (Cushing et al., 2017). Similarly, one study that aggregated EMA responses throughout the day found a non-significant within-person association between the percentage of the day spent in moderate or vigorous physical activity with aggregate levels of deactivation reported throughout the day (Kühnhausen et al., 2013).

3.4. *Affect as a predictor for physical activity in daily life*

Six studies examined affect as a predictor of physical activity (Cushing et al., 2018, 2017; Dunton et al., 2014; Koch et al., 2018; Rusby, Westling, Crowley, & Light, 2014; Wen et al., 2018). All of these studies were EMA studies, four reported device-measured MVPA as the outcome in windows ranging from 30 to 60 min following each EMA prompt (Cushing et al., 2018, 2017; Dunton et al., 2014; Wen et al., 2018), one used device-measured non-exercise physical activity (i.e., excluding physical activity accumulated during exercise) in the 10-min following an EMA prompt (Koch et al., 2018), and one study used self-reported activity as the outcome (Rusby et al., 2014). Predictors included positive and negative affect (Cushing et al., 2017; Dunton et al., 2014; Wen et al., 2018), valence (Koch et al., 2018), energy (Cushing et al., 2017; Dunton et al., 2014; Koch et al., 2018), tired or fatigued (Cushing et al., 2017; Dunton et al., 2014), and calmness (Koch et al., 2018). Additionally, one study included negative moods as predictors including depressed mood, anxiety and anger (Cushing et al., 2018), and one study included happiness as a predictor (Rusby et al., 2014).

All three studies with positive affect as a predictor found no significant within-person association between positive affect and subsequent MVPA in the 30-min (Cushing et al., 2017; Dunton et al., 2014; Wen et al., 2018) and 60-min (Wen et al., 2018) following and EMA prompt. However, the one study examining valence as a predictor found a significant positive within-person association between valence and subsequent non-exercise physical activity (Koch et al., 2018). Additionally, one study found participants were significantly more likely to report participating in physical activities when they were happier (Rusby et al., 2014).

All three studies examining negative affect and subsequent physical activity were EMA studies. All three of these studies found no significant within-person association between negative affect and MVPA in the subsequent 30-min (Cushing et al., 2017; Dunton et al., 2014; Wen et al., 2018) and 60-min (Wen et al., 2018). However, one study found that experiencing more depressed mood and feeling more angry than usual was related to lower levels MVPA in the subsequent 30-min following the prompt (Cushing et al., 2018). Feeling anxious did not have a within-person association with MVPA (Cushing et al., 2018).

Two of three studies found a positive within-person association between energy and subsequent physical activity. One study found that energy was associated with levels MVPA in the 30-min following a prompt and that this relationship was stronger in boys (Dunton et al., 2014). Another study found energetic arousal was related to the level of non-exercise physical activity in the subsequent 10-min (Koch et al., 2018). However, a single study found a non-significant relationship between energy and levels of MVPA in the 30-min following a prompt (Cushing et al., 2017). Additionally, both studies that reported on the within-person association between feeling tired or fatigued with physical activity found that feeling tired or fatigued did not predict levels of MVPA in the 30-min following a prompt (Cushing et al., 2017; Dunton et al., 2014). However, a single study found that being calmer than usual was related to lower levels of non-exercise physical activity in the 10-min following the prompt (Koch et al., 2018).

Table 2
Quality assessment of included studies.

Item	1	2	3	4	5	6	7	8	9	10	11	12
Cushing et al. (2017)	Y	Y	NR	Y	N	Y	Y	Y	Y	Y	Y	Y
Cushing et al. (2018)	Y	Y	NR	Y	N	Y	Y	Y	Y	Y	Y	Y
Dunton et al. (2014)	Y	Y	NR	Y	N	Y	Y	Y	Y	N	N	N
Gawrilow et al. (2016)	Y	Y	NR	Y	Y	Y	Y	Y	Y	Y	NR	Y
Koch et al. (2018)	Y	Y	NR	U	N	Y	Y	Y	Y	Y	Y	Y
Kolar et al. (2020)	Y	Y	NR	N	N	Y	Y	Y	Y	N	N	Y
Kühnhausen et al. (2013)	Y	Y	NR	U	N	U	U	Y	Y	N	N	Y
Langguth et al. (2016)	Y	Y	NR	U	N	Y	Y	Y	Y	N	NR	Y
Rusby et al. (2014)	Y	Y	Y	Y	N	N	U	N	N	N	N	Y
Wen et al. (2018)	Y	Y	NR	Y	N	Y	Y	Y	Y	N	N	Y

1 = Was the research question or objective in this paper clearly stated?, 2 = Was the study population clearly specified and defined?, 3 = Was the participation rate of eligible persons at least 50%?, 4 = Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?, 5 = Was a sample size justification, power description, or variance and effect estimates provided?, 6 = For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?, 7 = Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?; 8 = For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?, 9 = Was the measure of physical activity clearly defined, valid, reliable, and implemented consistently across all study participants?; 10 = Was the measure of affect clearly defined, valid, reliable, and implemented consistently across all study participants?, 11 = Was adherence 80% or greater?; 12 = Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?; Y = yes, N = no, U = unclear, NR = not reported.

4. Discussion

The purpose of this systematic review was to examine evidence of the bidirectional relationship between physical activity and affect in children and adolescents' daily life. The number of studies (k = 10) included in this review indicates that there has been a substantial increase in the quantity of research on the within-person relationship between physical activity and affect in young people's daily life since the 2015 review by Liao et al. (Liao et al., 2015). This highlights the increased research interest in understanding the relationship between physical activity and affect in young people's daily life, using ambulatory assessment techniques.

This review showed mixed evidence for the bidirectional relationship between physical activity and affect, which might at least partly be explained by the diversity of methods that were used for measuring physical activity and affect. Additionally, there were some common risks of bias in the included studies that must be considered. The majority of the studies included in the review had unrepresentative samples (i.e. self-referred samples), did not provide a-priori sample size calculations or ad-hoc power analysis, and used shortened versions of scales to measure affect without providing information on validity. This highlights some the challenges that researchers must overcome when conducting ambulatory assessment studies. Ambulatory assessment studies are time and resource intensive, which may make it difficult and costly to recruit large and representative samples of participants. Additionally, given that participants are surveyed on multiple occasions, researchers may need to shorten existing measures to reduce participant burden and increase compliance, possibly at the cost of validity. Promisingly, researchers have begun to develop and validate brief measurements specifically for ambulatory assessment (Wilhelm & Schoebi, 2007). Additionally, utilising progressive technologies such as smartwatches may have the potential to reduce participant burden and increase compliance (Intille, Haynes, Maniar, Ponnada, & Manjourides, 2016).

The strongest evidence identified in this review was the positive within-person association between physical activity and subsequent positive affect. Multiple EMA studies showed that when young people participated in greater levels of MVPA during daily life they reported significantly greater levels of positive affect (Cushing et al., 2017; Dunton et al., 2014; Kolar et al., 2020; Wen et al., 2018). Additionally, findings from EMA studies support a positive within-person association between physical activity and subsequent feelings of energy (Cushing et al., 2017; Dunton et al., 2014). This is consistent with the findings in adults that suggest participating in physical activity can have an immediate impact on positive feelings and vitality (Liao et al., 2015).

The findings regarding the within-person association between physical activity and subsequent negative affect were less conclusive. EMA studies included in this review did not find a within-person relationship between physical activity and subsequent negative affect or negative moods, such as depressed mood, anger and anxiety. However, there was some support for an inverse within-person relationship between physical activity and subsequent depressed mood in the daily diary studies in this review (Gawrilow et al., 2016; Langguth et al., 2016). This suggests that although physical activity may not have an acute impact on negative affect and moods, it is possible that accumulating greater levels of physical activity over extended periods of time has the potential to reduce negative feelings in young people.

Positive affect is operationalized as a combination of high valence and high activation, whereas negative affect is operationalized as low valence and high activation (Watson et al., 1988). Therefore, given that results showed that physical activity has a positive acute within-person relationship with positive affect, but no acute within-person association with negative affect suggests that young people do not experience pleasure when active. This is consistent with previous research conducted in controlled laboratory settings which found that although participating in moderate and vigorous intensity exercise may have an immediate positive effect on feelings of energy, it may have no effect or even a negative effect on valence (Benjamin, Rowlands, & Parfitt, 2012; Hamlyn-Williams, Freeman, & Parfitt, 2014; Malik, Williams, Weston, & Barker, 2017; Schneider & Graham, 2009; Sheppard & Parfitt, 2008). To confirm this, future research should specifically examine the within-person association between physical activity in daily life and subsequent valence.

Additionally, future studies should examine whether cognitive or contextual factors moderate the within-person association between physical activity and subsequent affect. A recent review found that contextual factors, such as whether physical activity is completed indoors or outdoors may moderate the within-person association between physical activity and valence (Bourke, Hilland, & Craike, 2020). There is also limited research young people which suggests that children may experience more positive affect when they are physically active outdoors compared to when active indoors (Dunton, Liao, Intille, Wolch, & Pentz, 2011). Additionally, research with adults found that the being active with others may augment the positive within-person association between physical activity and positive affect, and being active outdoors may augment the inverse within-person association between physical activity and negative affect (Dunton, Liao, Intille, Huh, & Leventhal, 2015). Another contextual factor that may also have the potential to moderate the within-person association between physical activity and subsequent affect is the type of physical activity (e.g. exercise, incidental physical activity) that young people participate in (Reichert et al., 2017). It is also possible that cognitive factors include motivation and competence or task self-efficacy may explain differences in affect experienced when active between-individuals (Bourke et al., 2020). Therefore, future studies should also examine whether affect experienced during physical activity in daily life differs between individuals with more positive and negative cognitive perceptions towards physical activity.

Results from this review showed that there was also mixed evidence for affect and moods predicting subsequent physical activity. Although studies included in this review found non-significant within-person associations between positive and negative affect and subsequent physical activity (Cushing et al., 2017; Dunton et al., 2014; Wen et al., 2018), valence and happiness were found to have a positive within-person association with physical activity in young people (Koch et al., 2018; Rusby et al., 2014). Additionally, negative moods such as depression and anger were found to have an inverse within-person association with subsequent physical activity in a single study (Cushing et al., 2018). There were also some support that young people may be more active when they are more energetic than usual (Dunton et al., 2014; Koch et al., 2018).

Future research should examine how manipulating affect may impact on physical activity participation in young people's daily lives. Meta-analytic research of adult studies demonstrated that inducing positive moods may lead to increased outcome expectancies towards physical activity which has the potential to increase participation in physical activity (Cameron, Bertenshaw, & Sheeran, 2015). Given that there is some support that young people may be more active when they experience more positive valence, greater levels of happiness, and less negative moods, it is possible that manipulating affect may increase levels of physical activity in young people. Incidental affect could be manipulated through the use of multi-media including video and music, affective imagery and recall, and self-affirmation strategies (Cameron et al., 2015). Additionally, researchers should consider how strategies to improve other health behaviours that can increase feelings of energy, such as getting recommended amounts of sleep (Triantafillou, Saeb, Lattie, Mohr, & Kording, 2019) or improving nutrition (O'Reilly et al., 2015), may also contribute to young people accumulating higher levels of physical activity.

Another potentially important area for future research is the impact of time on the relationship between physical activity and affect in children and adolescents. Interestingly, one study found that there was a positive within-person association between MVPA accumulated in the 30-min before a prompt and subsequent positive affect, but there was no within-person relationship when MVPA in the 60-min before a prompt was the predictor (Wen et al., 2018). This is consistent with previous research in adults which shows that the within-person association between physical activity and affect is strongest during or immediately following participation in physical activity and the effect dissipates over time (Reichert et al., 2017; Wichers et al., 2012). Research has also shown that the within-person effect of affect on subsequent physical activity is strongest over shorter timeframes before the magnitude of the effect weakens (Koch et al., 2018; Reichert et al., 2016). Most of the EMA studies identified in this review examined relationships with physical activity in 30-min timeframes preceding or proceeding an EMA prompt. Future studies should consider using shorter timeframes (e.g. 10–15 min) to see to what extent the within-person relationship between physical activity and affect is stronger over shorter time frames.

Additionally, researchers need to develop reliable and valid scales to measure affect repeatedly in daily life. This is important to reduce participant burden and increase compliance, without compromising validity. Multiple studies included in this review used selected items from the PANAS (Watson et al., 1988) and POMS (McNair et al., 1971), however they did not report validity of these shortened scales. Although validated short forms the PANAS already exist with five items each to measure positive and negative affect (Thompson, 2007), the results from the current study suggest it may be necessary to shorten the scale even further for use in ambulatory assessment. Additionally, researchers should consider the utility of single item measures of affect including the Feeling Scale (Hardy & Rejeski, 1989) and the Felt Arousal Scale (Svebak & Murgatroyd, 1985) which have been used extensively in exercise psychology to measure valence and energetic arousal respectively, but have been used sparingly in ambulatory assessment studies to date.

Although this paper provides a timely review of the acute bidirectional within-person association between physical activity and affect and moods in children and adolescents, there are some limitations that must be considered. First most of the studies included in this review used participant self-referral (e.g. responding to an advertisement) for recruitment, which could lead to selection-bias and therefore the samples may not be representative, and therefore the results may not be generalizable. Additionally, only one study included in the review provide a-priori sample size estimates, post hoc power analysis, or standardized effect size estimates. Therefore, it is possible the many of the included may have been under-powered and therefore vulnerable to type II error. A further limitation of this review, in addition to not providing standardized effect sizes, there was insufficient information in each of the articles to calculate standardized coefficients for within-person relationships between physical activity and affect. Specifically, no studies provided details of the within-person standard deviation for variables in their models (i.e. the square root of the level-1 variance in an unconditional model) (Nezleck, 2012). Therefore, without standardized regression coefficients, it was not possible to calculate correlation coefficients, and thus Fisher z, to use in a quantitative synthesis of results (Peterson & Brown, 2005). Additionally, heterogeneity between measures of physical activity and affect precluded the use of unstandardized regression coefficients in quantitative synthesis.

5. Conclusion

This systematic review identified studies that examined the bidirectional within-person association between physical activity and affect in children's and adolescents' daily life. Overall, ten studies reporting on nine unique samples were identified. Results indicated that there may be a positive within-person association between physical activity and subsequent positive affect and energy. There was less support for a within-person association between physical activity and subsequent negative affect, however, participating in greater levels of physical activity throughout the day than usual may be associated with decreased mood in the evening or following morning. There were mixed findings regarding the within-person association between affect and subsequent physical activity. Although positive and negative affect were not found to be associated with subsequent physical activity, results indicated that valence, happiness, and energy may be associated with greater levels of physical activity. Future research should consider the impact of contextual and cognitive factors and timing on the within-person relationship between physical activity and affect in children and adolescents. Additionally, future research should consider how manipulation of affect may influence physical activity participation in young people.

Authors contribution

MB conceptualised and designed this review, conducted the database searches, screened titles, abstracts and full texts, performed data extraction and wrote the manuscript. TAH screened titles, abstracts and full texts, checked data extraction and critically revised the manuscript. MC screened titles, abstracts and full texts, checked data extraction and critically revised the manuscript. All authors read and approved the final manuscript.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2020.101825.

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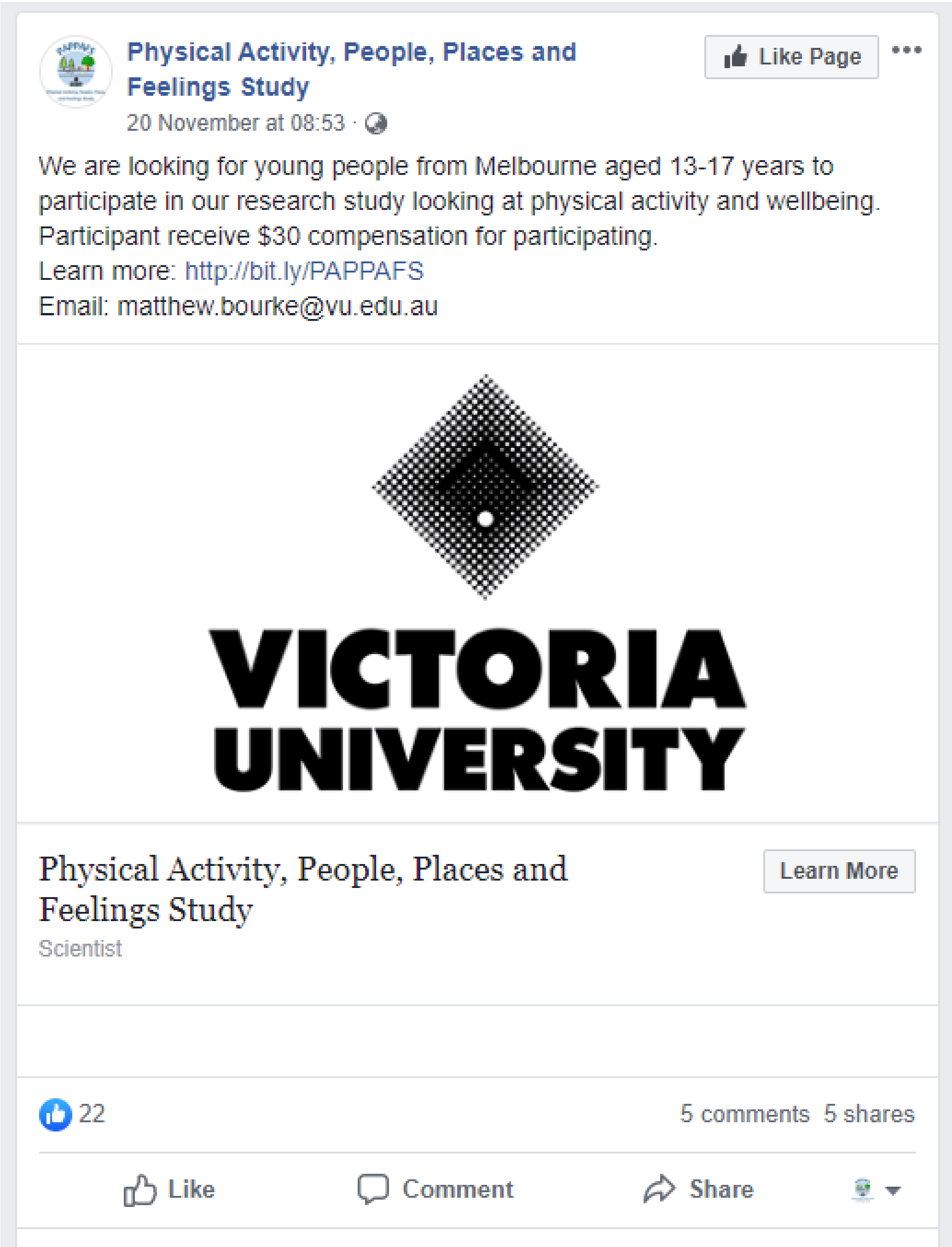
Appendix B: Example Recruitment Social Media Post



Appendix C: Information and Consent Forms

INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

You (or your child) are invited to participate

You (or your child) are invited to participate in a research project entitled "The physical activity, people, places, and feelings study".

This project is being conducted by a student researcher Mr Matthew Bourke as part of a PhD study at Victoria University under the supervision of Associate Professor Melinda Craike from the Institute for Health and Sport, and Dr Toni Hilland from the College of Design and Social Context at RMIT.

Project explanation

This project aims to see whether physical activity is associated with adolescents' mental wellbeing and satisfaction with life. The project also aims to examine if where and with who adolescents are physically active impacts on their mental wellbeing.

What will participants be asked to do?

Participants will be asked to answer questions on their mobile phones multiple times each day over a four day period. Each prompt will take roughly two minutes to complete. Participants will be asked to complete one prompt before school and four prompts after school on two school days, and nine prompts over the entire day on two weekend days. These questions will ask participants about how they feel (e.g. how well they feel, how energetic they are, if they are calm), where they are (e.g. at home, at the park, someone else's house), how they feel about an environment (e.g. is there much traffic, is there much vegetation, do they feel safe in the environment), who they are with (e.g. alone, with friends, with family), and who they feel about them (how well they know them, how important they are to them). We ask that participants answer as many prompts as possible, but if they are unable to access their phone or complete the prompt for any reason when they receive a notification, they can just ignore that notification and answer the next one.

Participants will also be asked to wear an accelerometer which the researchers will loan to them (see picture) on their dominant wrist to measure their physical activity during the day for four consecutive days. Participants will be asked to wear the accelerometer at all times unless they are sleeping, bathing, swimming or playing contact sports. Additionally, each evening of the four day period, participants will be asked to report physical activities that they completed during the day (e.g. riding to school, going for a walk, playing a sport). Each evening participants will also be asked questions about how they feel.

Participants can also volunteer to complete an interview to talk about being physically active, who they are active with, where they are active, and what makes them feel good or not so good when being active.

What will participants gain from participating?

By participating in this study, participants will help increasing understanding about what makes physical activity feel good which will help design programs in the future to encourage physical activity in adolescents. We also compensate all participants for one month's worth of mobile phone data of up to $30, which will be paid to them on a prepaid debit card. This amount of compensation is based on the average monthly cost of a prepaid mobile phone plan. Unfortunately, we cannot compensate any amount greater than $30, regardless of whether participants pay more for their mobile plan.

PLEASE TURN OVER THE PAGE

How will the information I give be used?

The information participants give will be pooled with information provided by all other respondents to conduct statistical analysis. The results from the statistical analysis will be used in a research report, academic publications and conference proceedings.

What are the potential risks of participating in this project?

There are some physical, psychological and social risks associated with this project that should be considered.

- There is a small risk that participants may be distracted while completing a prompt on their mobile phone which could lead to an accident and possible injury.
- Participating in this project may highlight feelings of loneliness and social isolation.
- Participants may feel peer pressure to participate in this project when they would rather not.

If participants are involved in an accident or do suffer and injury while partaking in the project they are advised to seek appropriate medical care.
If participants do become distressed as a result of the project they can access counselling services:

- Reach Out Australia (https://au.reachout.com/)
- Headspace (https://headspace.org.au/eheadspace/)
- Lifeline (13 11 14)

Participants can also contact the contact psychologist for this project, Dr Janet Young.
janet.young@vu.edu.au
9919 4762

How will this project be conducted?

For this project participants can go about their normal day-to-day life, and just answer the questions when they get a notification on their phone. Participants will have 30 minutes to open the prompt and answer the questions.

Who is conducting the study?

Mr Matthew Bourke
Institute for Health and Sport
Matthew.bourke6@live.vu.edu.au
0456461189

A/Prof Melinda Craike
Institute for Health and Sport
Melinda.craike@vu.edu.au
(03) 9919 5659

Any queries about participation in this project may be directed to the Investigators listed above.
If you have any queries or complaints about the way you or your child have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:
We would like to invite your child to be a part of a study titled “The physical activity, people, places, and feelings study”.

This project aims to see whether physical activity is associated with adolescents' mental wellbeing and satisfaction with life. The project also aims to examine if where and with who adolescents are physically active impacts on their mental wellbeing. More information about the project can be found in the **Information to Participants Involved in Research** form.

There are some physical, psychological and social risks associated with this project.

- There is a small risk that participants may be distracted while completing a prompt on their mobile phone which could lead to an accident and possible injury.
- Participating in this project may highlight feelings of loneliness and social isolation.
- Participants may feel peer pressure to participate in this project when they would rather not.

CERTIFICATION BY PARTICIPANT’S PARENT/GUARDIAN

I, [print your name] ____,

the parent/guardian of [print child’s name] ____

certify that I am 18 years or older and voluntarily giving my consent for my child to participate in the study:
“The physical activity, people, places, and feelings study” being conducted at Victoria University by Mr. Matthew Bourke, Associate Professor Melinda Craike, and Dr Toni Hilland.

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me by Mr. Matthew Bourke, that I understand the procedures and risks of the study, and that I freely consent to participation involving the below mentioned procedures:

Your child will be asked to:

- Answer questions on their mobile phone multiple times each day over a four day period. These questions will ask them about how they feel (e.g. how well they feel, how energetic they are, if they are calm), where they are (e.g. at home, at the park, someone else’s house), how they feel about an environment (e.g. is there much traffic, is there much vegetation, do they feel safe in the environment), who they are with (e.g. alone, with friends, with family), and how they feel about them (how well they know them, how important they are to them).

- Wear an accelerometer on their dominant wrist to measure their physical activity on four consecutive days (2 weekdays and 2 weekend days).

- Each evening of the four day period, report physical activities that they completed during the day (e.g. riding to school, going for a walk, playing a sport).

- Each evening answer questions about how they feel.

By checking the box below, you also agree that:

☐ Your child may be selected to complete an interview to talk about being physically active, who they are active with, where they are active, and what makes them feel good or not so good when being active.

PLEASE TURN OVER THE PAGE

I certify that I have had the opportunity to have any questions answered and that I understand that my child can be withdrawn from this study at any time and that this withdrawal will not jeopardise me or my child in any way.

I have been informed that the information I provide will be kept confidential.

Signed:

Date:

Any queries about your participation in this project may be directed to the researcher
Mr. Matthew Bourke
Institute for Health and Sport
Matthew.bourke6@live.vu.edu.au
0456461189

A/Prof Melinda Craike
Institute for Health and Sport
Melinda.craike@vu.edu.au
(03) 9919 5659

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

ASSENT FORM FOR ADOLESCENTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:
We would like to invite you to be a part of a study titled “The physical activity, people, places, and feelings study”.

This project aims to see whether physical activity is associated with adolescents' mental wellbeing and satisfaction with life. The project also aims to examine if where and with who adolescents are physically active impacts on their mental wellbeing. More information about the project can be found in the **Information to Participants Involved in Research** form.

There are some physical, psychological and social risks associated with this project.

- Participants may be distracted while completing a prompt on their mobile phone which could lead to an accident and possible injury.
- Participating in this project may highlight feelings of loneliness and social isolation.
- Participants may feel peer pressure to participate in this project when they would rather not.

CERTIFICATION BY PARTICIPANT

I, [print your name] ____,

certify that I wish to participate in the study:
“The physical activity, people, places, and feelings study” being conducted at Victoria University by Mr. Matthew Bourke, Associate Professor Melinda Craike, and Dr Toni Hilland.

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed below, have been fully explained to me by Mr. Matthew Bourke, that I understand the procedures and risks of the study, and that I volunteer to participate in procedures below:

- Answer questions on your mobile phone multiple times each day over a four day period. These questions will ask you about how you feel (e.g. how well you feel, how energetic you are, if you are calm), where you are (e.g. at home, at the park, someone else’s house), how you feel about an environment (e.g. is there much traffic, is there much vegetation, do I feel safe in the environment), who you are with (e.g. alone, with friends, with family), and how they feel about them (how well they know them, how important they are to them).

- Wear an accelerometer on your dominant wrist to measure your physical activity during the day for four consecutive days.

- Each evening, report physical activities that you completed during the day (e.g. riding to school, going for a walk, playing a sport).

- Each evening answer questions about how you feel.

By checking the box below, you also agree that:

- ☐ I may be selected to complete an interview to talk about being physically active, who I am active with, where I am active, and what makes me feel good or not so good when being active.

*****PLEASE TURN OVER THE PAGE*****

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this study at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the information I provide will be kept confidential.

Signed:

Date:

Any queries about your participation in this project may be directed to the researcher
Mr. Matthew Bourke
Institute for Health and Sport
Matthew.bourke6@live.vu.edu.au
0456461189

A/Prof Melinda Craike
Institute for Health and Sport
Melinda.craike@vu.edu.au
(03) 9919 5659

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

Appendix D: Ethics Approval

Matthew Bourke

From: quest.noreply@vu.edu.au
Sent: Friday, 1 February 2019 12:54 PM
To: Melinda.Craike@vu.edu.au
Cc: Matthew Bourke; toni.hilland@rmit.edu.au
Subject: Quest Ethics Notification - Application Process Finalised - Application Approved

Dear ASPR MELINDA CRAIKE,

Your ethics application has been formally reviewed and finalised.

» Application ID: HRE18-224
» Chief Investigator: ASPR MELINDA CRAIKE » Other Investigators: DR TONI HILLAND, MR MATTHEW BOURKE » Application Title: The physical activity, people, places, and feelings study (PAPPAFS).
» Form Version: 13-07

The application has been accepted and deemed to meet the requirements of the National Health and Medical Research Council (NHMRC) 'National Statement on Ethical Conduct in Human Research (2007)' by the Victoria University Human Research Ethics Committee. Approval has been granted for two (2) years from the approval date; 01/02/2019.

Continued approval of this research project by the Victoria University Human Research Ethics Committee (VUHREC) is conditional upon the provision of a report within 12 months of the above approval date or upon the completion of the project (if earlier). A report proforma may be downloaded from the Office for Research website at: http://research.vu.edu.au/hrec.php.

Please note that the Human Research Ethics Committee must be informed of the following: any changes to the approved research protocol, project timelines, any serious events or adverse and/or unforeseen events that may affect continued ethical acceptability of the project. In these unlikely events, researchers must immediately cease all data collection until the Committee has approved the changes. Researchers are also reminded of the need to notify the approving HREC of changes to personnel in research projects via a request for a minor amendment. It should also be noted that it is the Chief Investigators' responsibility to ensure the research project is conducted in line with the recommendations outlined in the National Health and Medical Research Council (NHMRC) 'National Statement on Ethical Conduct in Human Research (2007).'

On behalf of the Committee, I wish you all the best for the conduct of the project.

Secretary, Human Research Ethics Committee
Phone: 9919 4781 or 9919 4461
Email: researchethics@vu.edu.au

This is an automated email from an unattended email address. Do not reply to this address.

Appendix E: Self-Reported EMA Items

Construct	Question
Physical environment location	Where are you right now? 1. Home 2. School 3. Vehicle 4. Outdoors 5. Other *If Other* 1. Restaurant 2. Shopping Centre 3. Someone else's house 4. Gym/Recreation centre 5. Someplace else
Social context	Are you alone right now? 1. Yes 2. No *If no* Who are you with right now? 1. Friend 2. Sibling 3. Parent 4. Other family member 5. Neighbour 6. Stranger
Activity type	What were you doing right before you opened this prompt? 1. Physical activity or exercise 2. Reading or doing homework 3. Using social media 4. Playing computer/video games 5. Watching TV or a movie 6. Eating a meal 7. Housework or chores (e.g. cleaning the house, gardening) 8. Other (please specify) *If physical activity or exercise* What sort of physical or activity were you doing? 1. Walking for fun or exercise (including on a treadmill) 2. Walking to get from place to place (e.g. to get to school, to go to the shops) 3. Riding my bike, scooter or skateboard for fun or exercise (including stationary bike)

	4. Riding my bike, scooter or skateboard to get from place to place (e.g. to get to school, to go to the shops) 5. Running (including on a treadmill) 6. Playing a sport or physically active game 7. Dancing 8. Gym or group fitness class 9. Swimming 10. Gymnastics or cheerleading 11. Yoga or pilates 12. Other (please specify)
Affect	At this moment I feel: (1) Very tired – Very Awake (7) (1) Very discontent – Very content (7) (1) Very agitated – Very calm (7) (1) Very unenergetic – Very energetic (7) (1) Very unwell – Very well (7) (1) Very tense – Very relaxed (7)

Appendix F: Domain Specific Association Between Physical Activity and Affect Sensitivity Analysis

	Valence			*Energetic Arousal*			*Tense arousal*		
	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Fixed effects, model parameter									
Intercept, β_{00}	**13.13**	**3.05**	**<.001**	**15.09**	**3.90**	**<.001**	4.85	3.03	.113
Sex (Female referent), γ_{01}	0.53	0.30	.083	0.76	0.39	.053	-0.32	0.30	.288
Age, γ_{02}	-0.06	0.11	.555	-0.06	0.14	.666	-0.04	0.11	.719
SES, γ_{03}	-0.00	0.00	.643	-0.001	0.00	.219	0.00	0.00	.731
Day of week (Weekend referent), β_{10}	**-0.27**	**0.13**	**.044**	**-0.60**	**0.19**	**.002**	0.13	0.16	.420
Time of day (Morning referent), β_{20}									
Afternoon	**0.33**	**0.10**	**.002**	**0.74**	**0.19**	**<.001**	-0.21	0.13	.090
Evening	**0.38**	**0.11**	**.001**	0.24	0.20	.240	**-0.36**	**0.13**	**.007**
Recreational MVPA (within) β_{30}	0.02	0.02	.773	**0.18**	**0.04**	**<.001**	**0.07**	**0.03**	**.027**
Recreational MVPA (between), γ_{04}	0.61	0.32	.055	**1.30**	**0.40**	**.002**	**-0.83**	**0.32**	**.010**
Active travel (within), β_{40}	0.03	0.05	.498	0.10	0.07	.147	-0.06	0.05	.294
Active travel (between), γ_{05}	-0.18	0.48	.705	-0.18	0.61	.764	0.43	0.48	.368
Household MVPA (within), β_{50}	0.04	0.04	.915	0.11	0.06	.092	0.01	0.05	.913
Household MVPA (between), γ_{06}	-0.66	0.54	.226	-0.65	0.68	.345	0.59	0.54	.271
Random effects									
Residual, r_{ti}	**2.02**	**0.08**	**<.001**	**4.93**	**0.21**	**<.001**	**2.99**	**0.12**	**<.001**
Intercept, μ_{0i}	**1.56**	**0.30**	**<.001**	**2.23**	**0.50**	**<.001**	**1.41**	**0.30**	**<.001**
Day of the week, μ_{1i}	**0.48**	**0.12**	**<.001**	**0.79**	**0.23**	**<.001**	**0.61**	**0.15**	**<.001**
Time of day, μ_{2i}	-	-	-	**0.43**	**0.17**	**.010**	-	-	-

Appendix G: Contextual Influences on the Within-Person Association Between Physical Activity and Affect Sensitivity Analysis

Table G1 Results from multilevel models predicting valence

	Model 1			***Model 2***			***Model 3***		
	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Fixed effects, model parameter									
Intercept, β_{00}	**12.01**	**3.04**	**<.001**	**12.00**	**3.04**	**<.001**	**12.00**	**3.04**	**<.001**
Sex (Female referent), γ_{01}	**0.67**	**0.30**	**.027**	**0.67**	**0.30**	**.027**	**0.67**	**0.30**	**.028**
Age, γ_{02}	-0.07	0.11	.507	-0.07	0.11	.510	-0.07	0.11	.507
SES, γ_{03}	0.00	0.00	.991	0.00	0.00	.990	0.00	0.00	.990
Day of week (Weekend referent), β_{10}	-0.22	0.14	.105	-0.21	0.14	.105	-0.22	0.14	.112
Time of day (Morning referent), β_{20}									
Afternoon	**0.35**	**0.10**	**<.001**	**0.35**	**0.10**	**<.001**	**0.35**	**0.10**	**<.001**
Evening	**0.47**	**0.11**	**<.001**	**0.47**	**0.11**	**<.001**	**0.47**	**0.11**	**<.001**
Weather (Fine referent), β_{30}									
Overcast	-0.24	0.13	.065	-0.24	0.13	.076	-0.24	0.13	.063
Raining	**-0.57**	**0.21**	**.008**	**-0.57**	**0.21**	**.008**	**-0.57**	**0.21**	**.008**
Temperature (Pleasant referent), β_{40}									
Too cold	**-0.33**	**0.11**	**.007**	**-0.32**	**0.11**	**.007**	**-0.34**	**0.11**	**.007**
Too hot	-0.30	0.18	.070	-0.30	0.18	.075	-0.30	0.18	.064
Physical environment (Indoors referent), β_{50}	0.26	0.13	.055	**0.28**	**0.14**	**.048**	0.26	0.13	.054
Social context (alone referent), β_{60}	0.05	0.10	.618	0.05	0.10	.632	0.06	0.10	.586
MVPA, β_{70}	0.02	0.02	.237	0.03	0.02	.201	-0.01	0.04	.821
MVPA * physical environment, β_{80}	-	-	-	-0.02	0.05	.626	-	-	-
MVPA * social context, β_{80}	-	-	-	-	-	-	0.04	0.04	.364
Fixed effects, model parameter									
Residual, r_{ti}	**1.94**	**0.08**	**<.001**	**1.94**	**0.08**	**<.001**	**1.94**	**0.08**	**<.001**
Intercept, μ_{0i}	**1.49**	**0.32**	**<.001**	**1.49**	**0.32**	**<.001**	**1.50**	**0.32**	**<.001**
Day of week, μ_{1i}	**0.48**	**0.12**	**<.001**	**0.48**	**0.12**	**<.001**	**0.48**	**0.12**	**<.001**
Weather, μ_{3i}	0.15	0.09	.094	0.15	0.09	.093	0.15	0.09	.107

Table G2 Results from multilevel models predicting energetic arousal

	Model 1			*Model 2*			*Model 3*		
	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Fixed effects, model parameter									
Intercept, β_{00}	**12.28**	**4.05**	**.003**	**12.29**	**4.04**	**.003**	**12.22**	**4.05**	**.003**
Sex (Female referent), γ_{01}	**1.02**	**0.40**	**.012**	**1.02**	**0.40**	**.012**	**1.01**	**0.40**	**.012**
Age, γ_{02}	-0.04	0.15	.769	-0.04	0.15	.771	-0.04	0.15	.768
SES, γ_{03}	-0.00	0.00	.374	-0.00	0.00	.372	-0.00	0.00	.382
Day of week (Weekend referent), β_{10}	**-0.57**	**0.19**	**.003**	**-0.57**	**0.19**	**.003**	**-0.56**	**0.19**	**.004**
Time of day (Morning referent), β_{20}									
Afternoon	**0.83**	**0.20**	**<.001**	**0.83**	**0.20**	**<.001**	**0.84**	**0.19**	**<.001**
Evening	**0.41**	**0.20**	**.043**	**0.42**	**0.20**	**.040**	**0.41**	**0.20**	**.042**
Weather (Fine referent), β_{30}									
Overcast	**-0.51**	**0.17**	**.002**	**-0.51**	**0.17**	**.002**	**-0.51**	**0.17**	**.002**
Raining	**-0.98**	**0.29**	**<.001**	**-0.99**	**0.29**	**<.001**	**-0.99**	**0.29**	**<.001**
Temperature (Pleasant referent), β_{40}									
Too cold	**-0.42**	**0.17**	**.016**	**-0.41**	**0.17**	**.017**	**-0.41**	**0.17**	**.019**
Too hot	**-0.64**	**0.28**	**.022**	**-0.62**	**0.28**	**.027**	**-0.65**	**0.28**	**.020**
Physical environment (Indoors referent), β_{50}	**0.84**	**0.28**	**.004**	**0.92**	**0.28**	**.002**	**0.85**	**0.28**	**.003**
Social context (alone referent), β_{60}	**0.46**	**0.16**	**.005**	**0.45**	**0.16**	**.005**	**0.47**	**0.16**	**.004**
MVPA, β_{70}	**0.12**	**0.03**	**<.001**	**0.13**	**0.03**	**<.001**	0.04	0.06	.463
MVPA * outdoors, β_{80}	-	-	-	-0.09	0.08	.267	-	-	-
MVPA * social context, β_{80}	-	-	-	-	-	-	0.10	0.07	.161
Random effects, model parameter									
Residual, r_{ti}	**4.50**	**0.20**	**<.001**	**4.50**	**0.20**	**<.001**	**4.25**	**0.18**	**<.001**
Intercept, μ_{0i}	**2.56**	**0.54**	**<.001**	**2.56**	**0.54**	**<.001**	**2.33**	**0.45**	**<.001**
Day of week, μ_{1i}	**0.79**	**0.23**	**<.001**	**0.79**	**0.23**	**<.001**	**0.79**	**0.21**	**<.001**
Time of day, μ_{2i}	**0.47**	**0.17**	**.005**	**0.46**	**0.17**	**.006**	**0.42**	**0.14**	**.004**
Physical environment, μ_{5i}	**1.97**	**0.83**	**.017**	**1.86**	**0.80**	**.020**	**1.86**	**0.72**	**.010**

	Model 1			***Model 2***			***Model 3***		
	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Fixed effects, model parameter									
Intercept, β_{00}	5.61	3.06	.070	5.56	3.06	.072	5.60	3.05	.070
Sex (Female referent), γ_{01}	-0.48	0.30	.116	-0.47	0.30	.122	-0.48	0.30	.115
Age, γ_{02}	-0.02	0.11	.863	-0.02	0.11	.880	-0.02	0.11	.861
SES, γ_{03}	-0.00	0.00	.930	-0.00	0.00	.931	-0.00	0.00	.931
Day of week (Weekend referent), β_{10}	0.08	0.15	.587	0.08	0.15	.598	0.09	0.15	.576
Time of day (Morning referent), β_{20}									
Afternoon	-0.21	0.13	.106	-0.21	0.13	.105	-0.21	0.13	.108
Evening	**-0.39**	**0.13**	**.004**	**-0.38**	**0.13**	**.005**	**-0.39**	**0.13**	**.004**
Weather (Fine referent), β_{30}									
Overcast	0.17	0.13	.210	0.17	0.13	.200	0.17	0.13	.211
Raining	0.27	0.23	.241	0.26	0.23	.263	0.27	0.23	.245
Temperature (Pleasant referent), β_{40}									
Too cold	0.17	0.16	.278	0.18	0.16	.256	0.17	0.16	.273
Too hot	**0.84**	**0.25**	**<.001**	**0.86**	**0.25**	**<.001**	**0.83**	**0.25**	**<.001**
Physical environment (Indoors referent), β_{50}	-0.18	0.17	.270	-0.08	0.17	.627	-0.18	0.17	.272
Social context (alone referent), β_{60}	0.04	0.13	.729	0.04	0.13	.779	0.05	0.13	.714
MVPA, β_{70}	0.03	0.02	.142	**0.05**	**0.02**	**.033**	0.02	0.05	.729
MVPA * outdoors, β_{80}	-	-	-	**-0.12**	**0.06**	**.050**	-	-	-
MVPA * social context, β_{80}	-	-	-	-	-	-	0.02	0.05	.681
Random effects									
Residual, r_{ti}	**2.90**	**0.12**	**<.001**	**2.89**	**0.12**	**<.001**	**2.90**	**0.12**	**<.001**
Intercept, μ_{0i}	**1.37**	**0.32**	**<.001**	**1.37**	**0.32**	**<.001**	**1.36**	**0.32**	**<.001**
Day of week, μ_{1i}	**0.54**	**0.14**	**<.001**	**0.55**	**0.15**	**<.001**	**0.54**	**0.15**	**<.001**
Temperature, μ_{4i}	**0.25**	**0.12**	**.041**	**0.24**	**0.12**	**.046**	**0.25**	**0.12**	**.041**

Appendix H: Qualitative Interview Schedule

Hello, my name is Matthew Bourke, and I am a PhD student at Victoria University. I want to start off by taking the time to thank you for agreeing to participate in this interview. This interview is part of the project that you have already participated in. Do you remember where you were asked to wear an accelerometer and complete questions on your phone about how you felt, where you were and who you were with?

Before we begin, I need to let you know that this interview is being recorded and will be transcribed and used in my PhD thesis and other academic publications. What you say may be published in these documents, however I will not use your name, I will use a made-up name, and any identifying features will be removed. If for any reason you would like me to stop recording the interview, please just ask and I will stop it. Now can I please get you to state your first name for the recording for me?

Can you confirm that I've explained what we'll be doing today to you before and that you volunteer to do this interview.

During this interview I'm just going to ask you a few questions about physical activity and how it makes you feel. Can you have a go at defining physical activity for me?

For the purpose of this interview, we will define physical activity as any type of bodily movement that raises your heart rate, even slightly, so this includes things like playing organised sport including training, walking or cycling to get to places, doing chores around the house, playing physically active games with friends, and participating in school PE.

1. To help me get some idea about your physical activity, can you describe to me the physical activities you have participated in in the last month?
2. Are there other physical activities that you used to participate in regularly before Covid-19 that you can't participate in now?
3. Thinking about when you have been physically active in the past month, can you give me an example of when you found participating in physical activity a pleasant experience?
4. Can you describe to me why it was that you found participating in this physical activity pleasant?
5. Are there physical activities that you participated in before the pandemic that you found pleasant that you are not able to participate in now?
6. What is it about these activities that you miss the most?
7. This is a very stressful and tense time, so I was wondering you participate in any type of physical activity feel calmer or more relaxed?
8. What is it about these physical activities that you find calming and how do they help to reduce your stress?
9. What about when you need a pick-me-up or need to feel more energised? Do you feel more energetic when you participate in physical activities?
10. What is it about participating in physical activities that give you more energy? (Why don't you feel more energetic when participating in physical activities?)

Appendix I: Self-Reported Daily Diary Items

Satisfaction with life

All things considered, how satisfied are you with your life as a whole today?

(1) Not at all satisfied – Completely satisfied (10)

Household physical activity

The following questions are about physical activities that you have done today around the house.

Did you do any physical activities for at least 10 minutes at a time in the garden or home that took at least moderate physical effort and make you breathe somewhat or much harder than normal like carrying heavy loads, scrubbing floors, sweeping? Don't include activities that took less than 10 minutes to complete.

- Yes
- No

If yes

How much time did you spend today on those activities at home or in the yard?

Hours ___

Minutes ___

The following questions are about how you travelled from place to place, including to places like school, stores, movies, and so on.

Active travel

The following questions are about how you travelled from place to place, including to places like school, stores, movies, and so on.

Did you bicycle, scoot or skate for at least 10 minutes at a time today to go from place to place?

- ○ Yes
- ○ No

If yes

How much time did you spend today bicycling, skating and scooting from place to place?

Hours ___

Minutes ___

Did you walk for at least 10 minutes at a time today to go from place to place?

- ○ Yes
- ○ No

If yes

How much time did you spend today walking from place to place?

Hours ___

Minutes ___

Leisure-time physical activity

This section is about all the physical activities that you did today solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

Did you walk for at least 10 minutes at a time today in your leisure time?

- ○ Yes
- ○ No

If yes

How much time did you spend today walking in your leisure time?

Hours ___

Minutes ___

Thinking back to all the physical activities that you did today for at least 10 minutes at a time, did you do moderate physical activities like dancing, swimming at a regular pace, and doubles tennis in your leisure time?

- ○ Yes
- ○ No

If yes

How much time did you spend today doing moderate physical activities in your leisure time?

Hours ___

Minutes ___

Thinking back to all the physical activities that you did today for at least 10 minutes at a time, did you do vigorous physical activities like aerobics, running, fast bicycling or fast swimming in your leisure time?

- Yes
- No

If yes

How much time did you spend today doing vigorous physical activities in your leisure time?

Hours ___

Minutes ___

Appendix J: Multilevel Mediation Model Equations

Mediation model (between person): Self-reported leisure-time physical activity → Energetic arousal → Satisfaction with life

Step 1

Level 1

$$Energetic\ arousal = \beta_{00} + \beta_{10}(Daily\ leisure\ time\ physical\ activity_{ti}) + r_{ti}$$

Level 2

$$\beta_{00} = \gamma_{00} + \gamma_{01}\ (Average\ leisure\ time\ physical\ activity_{i}) + \mu_{0i}$$

$$\beta_{10} = \gamma_{10}$$

Step 2

Level 1

$$\begin{aligned} Satisfaction\ with\ life_{ti} &= \beta_{00} \\ &+ \beta_{10}(Daily\ leisure\ time\ physical\ activity_{ti}) \\ &+ \beta_{20}(Daily\ energetic\ arousal_{ti}) + r_{ti} \end{aligned}$$

Level 2

$$\begin{aligned} \beta_{00} = \gamma_{00} + \gamma_{01}\ &(Average\ leisure\ time\ physical\ activity_{i}) \\ &+ \gamma_{02}\ (Average\ energetic\ arousal_{i}) + \mu_{0i} \end{aligned}$$

$$\beta_{10} = \gamma_{10}$$

$$\beta_{20} = \gamma_{20}$$

Mediation model (between person): Device-measured vigorous intensity physical activity → Energetic arousal → Satisfaction with life

Step 1

Level 1

$$\begin{aligned} Energetic\ arousal &= \beta_{00} + \beta_{10}(Daily\ vigorous\ time\ physical\ activity_{ti}) \\ &+ \beta_{20}(Daily\ accelerometer\ wear\ time_{ti}) + r_{ti} \end{aligned}$$

Level 2

$$\begin{aligned} \beta_{00} = \gamma_{00} + \gamma_{01}\ &(Average\ leisure\ time\ physical\ activity\ PA_{i}) \\ &+ \gamma_{02}\ (Average\ accelerometer\ wear\ time_{i}) + \mu_{0i} \end{aligned}$$

$$\beta_{10} = \gamma_{10}$$

$$\beta_{20} = \gamma_{20}$$

Step 2

Level 1

$$Satisfaction\ with\ life_{ti} = \beta_{00} + \beta_{10}(Daily\ vigorous\ time\ physical\ activity_{ti}) + \beta_{20}(Daily\ accelerometer\ wear\ time_{ti}) + \beta_{30}(Daily\ energetic\ arousal_{ti}) + r_{ti}$$

Level 2

$$\beta_{00} = \gamma_{00} + \gamma_{01}\ (Average\ leisure\ time\ physical\ activity\ PA_{i}) + \gamma_{02}\ (Average\ laccelerometer\ wear\ time_{i}) + \gamma_{03}\ (Average\ energetic\ arousal_{i}) + \mu_{0i}$$

$$\beta_{10} = \gamma_{10}$$

$$\beta_{20} = \gamma_{20}$$

$$\beta_{30} = \gamma_{30}$$